THE LAW

OF

SEX DETERMINATION

AND ITS

PRACTICAL APPLICATION

BY

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THIS WORK

IS

DEDICATED

TO ALL WHO MAY BE MINDED TO LOOK INTO THE MYSTERIES
OF THIS MUTABLE EARTH-LIFE AND INVESTIGATE
THE VARIOUS MEANS OF ITS GREAT
PROGRESSIONS

PREFACE.

THE problem of sex determination has always been of great interest. It has been the subject of investigation at all times, and has been supposed to have many solutions. These solutions have usually proved to be founded on nothing better than conjecture and coincidence, the two factors that vitiate so many investigations with regard to things human. During the last two or three generations there have been so many disappointments in this matter that there has come to be a very general impression that the problem would never be solved. The present volume is a contribution to the subject founded on observation in human beings and experiments in cattle breeding. The writer is convinced that at least very definite progress toward the solution of the problem, if not its actual solution, has been made by these studies. And they are here presented to the public entirely with the idea of securing scientific control, and it is hoped eventual confirmation of this law, by further observation and experiment conducted under such variant conditions as will test it effectively.

Publication has not been undertaken hurriedly, though this subject might be presumed to be a sensational and popular idea. Not only have the studies been pursued for years, but a number of distinguished biologists have been consulted, and all of them agreed that the subject was worthy of thorough consideration, and that the work that had been done should be published in order that further investigation of a like nature from differing

standpoints might be made. In order that the subject should be better understood, and that the scope in biological investigation in cognate subjects in recent years should be better known, a number of contributions in the recent biological literature relating to this subject and to cognate topics have been quoted. These serve not only to give information that is interesting in itself, but also indicate how much progress is being made in subjects and with regard to biological relations that were formerly, and that not so very long ago, thought to be quite outside the domain of investigation. It is evident that there are a great many questions relating to human origins that are to lose most of their mystery in the near future, and sex determination would seem to be one of these that has now yielded to patient research. This work does not pretend to explain or analyze the phenomena of the presence of the two sexes among beings nor the possibility of a neutral sex among them, but it has to do with the knowledge of manifest mechanics that determine which of the two sexes shall appear in offspring. The observation has been made that there is a definite check on any tendency that might exist in humanity toward an overproduction, or even an overpreservation, of either sex; that nature has some means even of restoring the equilibrium of the sexes when that has been disturbed by unusual conditions in humanity. After the Thirty Years' War, for instance, in Germany so many men had perished in battle, by pestilence in camp, by ineffectual medical and surgical assistance, from famine because of neglect of agriculture and the waste of planted territory, that it is said there were two women alive for every man in the region we now know as the German Empire. Because of this some of the German states relaxed their marriage laws and allowed a man to have two wives. The balance

of the sexes, it is stated, at once began to restore itself, and before the end of the century the normal equilibrium of the sexes had once more been reëstablished.

Such biological mutations with regard to the ratio of the sexes have also been noted in other animals as well as man, and these have been employed with the idea of throwing light on cases similar to the classical example of the German population after the Thirty Years' War. The question of the explanation of them has been taken up very seriously. A few years ago it was thought that some very significant and definite conclusions in the matter had been reached from experiments and observations on tadpoles. Some were led to believe that by feeding embryonic forms of the frog in various ways when they were sexless great influence might be exerted upon sex formation. Embryos fed luxuriantly developed into females in much greater proportion than usual, while those scantily fed developed more frequently into males.

Unfortunately, further experiments and observations have not confirmed this conclusion, though as yet there are many biologists who consider that there is something in it, and that this is one mode of investigating nature's methods in the determination of sex. Apply this conclusion to the case above cited of a restoration of the equilibrium of the sexes after the Thirty Years' War. At times when men are in small proportion in the population, women have to work much harder, the means of sustenance are limited, and the human embryos, therefore, may be expected to receive much less nutrition than usual, or, at least, to be much less likely to have a superabundance of nutrition, and therefore, because of these privations and vicissitudes during the Thirty Years' War, according to this theory, a great preponderance of boy babies

would have been born in the German states *during* thirty years, and therefore, at the *end* of that period, could there have been two women for every man? And according to this theory, *after* the war, in case there were two women to every man, the mothers being more luxuriantly fed, war ended, the men at home, it would seem that the equilibrium would continue to be disturbed by the preponderance of girl babies born—if luxuriant or scanty nutrition determine sex. It is easy to see why there should be the supposition of scanty or luxuriant nutrition as determining factors in the sex of cattle, although such a theory has not been susceptible of substantiation, and the so-called "hunger sex" among them is reasonably accounted for along other lines in the light of the sex-determining law as the author understands it.

These and such considerations serve to show that evidently the problem of sex determination was not solved by processes of nutrition, and yet that it is just a biological problem that will have its solution and probably in some very simple way. A great American biologist once said that Nature always accomplishes her purposes much more simply than the philosophic theorist or maker of scientific hypotheses is likely to think. And, indeed, it is a simple solution of this problem that is found. The explanation offered in this book might very well be applied to the conditions that are said to have existed after the Thirty Years' War, since in times of hardship and severe labor the positions assumed before and during sleep are likely to have definite reference to the muscles that have been employed during the day and their mode of employ. We know nothing, then, that in any way contradicts the idea here advanced, and much that seems to suggest that some such simple explanation is probably the correct solution of this interesting problem.

While the writer has carefully investigated the conditions of the problem, and has come definitely to the conclusion here announced, and is familar with the biological literature relating to the subject, she feels that trained biologists will probably find here and there in the work traces of the amateur rather than of the professional biological worker. Dealing with a difficult subject, she would crave indulgence for such inaccuracies in the use of terms as may have occasionally crept in. The subject is placed before the scientific world with the definite idea of eliciting opinions and proving an incentive to other work along the same line. We have learned so much about human conditions by observation and experiment in late years, and the outlook for future biology is so promising because of recent studies, that this contribution is offered not for its popular interest, but for the sake of quickening at once the practical and scientific consideration of the same problem.

LAURA A. CALHOUN.

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PART I.

THE LAW OF SEX DETERMINATION AMONG HUMAN BEINGS AND HIGHER ANIMALS, WITH THE DISCUSSION OF SOME THEORIES OF SEXUAL BIOLOGY WHICH THIS LAW SEEMS TO ENTAIL.

THE LAW OF SEX DETERMINATION AND ITS PRACTICAL APPLICATION.

PURPOSE OF THIS WORK.

The purpose of this work is to set forth as well as may be two theses: one concerns the law which determines the sex of the embryo in man and the higher animals, and the other a practical application of the theory thus involved to the needs of human life.

CHAPTER I.

SEX-DETERMINING FACTORS IN THE REPRODUCTION OF HUMAN BEINGS AND HIGHER ANIMALS, AND THEIR DIFFERENT MODES OF OPERATION.

THEORY OF SEX DETERMINATION.

The writer maintains that the sex of the embryo in man and the higher animals is determined in the ovary from which the ovum in question is developed. In the normal female the ovary of the right side yields ova which on fertilization develop as males, and the ovary of the left side yields ova which are potentially female. (See Plate I.)

VOLUNTARY DETERMINATION OF SEX.

If the above thesis is true, it is possible in human life to determine sex at will by some method which will provide that only those ova of the sex desired shall become fertilized. To this end the influence of gravitation can be utilized. The ova are met by the spermatozoa at or near the ovary. The direction that these fertilizing spermatozoa take, whether passing to

the right ovary or the left ovary, must depend largely upon the law of gravity; that is, the spermatozoa would be carried by the fluid which contains them, according to the law of gravity, their power of locomotion affected not only by their own natural actively aggressive quality, but, as has been demonstrated, by their contact with the ciliary movements in the epithelium lining the passages.

In order that fertilizing spermatozoa shall reach the right or left ovary, it is necessary that gravity should carry them in the direction desired. (See page 44, Chapter II.)

VERIFICATION OF THIS THEORY.

Certain scientists have suggested, including Ahlfeld, Schultz, Cuénot, Beard, and others, a theory that the sex of human offspring is determined in the egg; that is, that all human ova contain at the same time both sexes, potentially, and that the sex of the developing embryo of a given ovum is finally determined—whether it is to be male or female—according to influences to which the germ cell is subjected before or at fertilization. Some hold that these influences are the result of the nutrition received by the mother during pregnancy; some that they are dependent upon the laws of dominance, segregation, etc.

Within a few weeks there has been reviewed another egg theory, by E. Rumley Dawson, who claims, however, that the sex of the offspring is dependent upon a monthly periodic ovulation, alternating male and female ova, and that this period is manifested only by the monthly menstruation. (For this last egg theory, see Appendix, page 247.) And as a consequence of this alternating periodic ovulation of male and female ova, its author claims that he is able by careful data from the mother to forecast after the first born the sex of a child to be born; and, also, that after the first child born, he would be able from this exact and careful data from the mother possibly to determine the sex of the next child to be conceived. However, up to the present none of these egg theories have received adequate verification.

PRACTICAL VERIFICATION.

The writer is not in a position to furnish absolute verification, through methods of anatomy or physiology, of her theory. She has no laboratories nor methods of precision by which her theory can be directly tested. But she is convinced of its truth from her own extensive experience in its practical application for a period of thirty years. She lived on a ranch in one of the mountain valleys in Southern California,

and there experimented with flowers, vegetables, and fruits. The result was that interesting and fantastic qualities in color, size, and shape appeared among them. These experiments were made not as a student of science, but as a lover of nature.[1] (See Appendix, page 249.)

The cattle, goats, and pigs were slaughtered on the ranch, and the size, shape, color, and location of the nerves, fibers, filaments, ganglia, and vitals of the dissected animals were as instructive and interesting as the living animals' personalities and habits. (See Appendix, page 250.)

A considerable acquaintance was made with the nature and habits of fowls, also with the growth and maturation of their interior structure.

The horses and cattle were so generously endowed with the elemental qualities of the primitive human being that they made first-rate companions. They are exceedingly entertaining in their affections and jealousies for their own kind, as well as their likes and dislikes for human beings.

[1] My husband, Judge E. E. Calhoun, on account of his official and business duties, was obliged to remain at Bakersfield, the county seat, a great deal of the time. Because of this necessity, my solitude, I realize now, was the best possible opportunity for acquiring knowledge of some of Nature's facts concerning the plant and animal life on our ranch.

Scarcely less interesting and instructive than these creatures were those of the almost microscopic life.

It was from the ardent desire of having and always seeking, that, little by little, from here and from there, the principles of the law of sex determination became manifest to her. And according to this law a son was born to her. Afterward, from time to time, friends were instructed when they would desire a son or a daughter. The results have always verified the law, which during thirty years of observation and testing have never failed.

RECORD OF CASES.

For obvious reasons actual names cannot be given, but the accuracy of the following is vouched for and represents a variety of phases of the law of sex determination in different experiences:

Mrs. J. C., of Bakersfield, California, after having given birth to six or seven sons successively, after following these directions gave birth to a daughter in 1880.

Mrs. N. E. E. C., of Bakersfield, California, had given birth to six daughters successively, and after that, according to these directions, gave birth to a son.

Mrs. J. H., of Caliente, California, in 1880, wish-

ing her first child to be a son, according to these directions gave birth to a son; also, desiring the second child to be a son, two years after, by these same directions, gave birth to the second son. Then wishing a daughter, according to these directions, in 1885 gave birth to a daughter.

Mrs. T. B., of Bakersfield, California, had given birth to four sons successively. Her right ovary became diseased and her physician found it necessary to remove it; but as her left ovary seemed healthy and normal, it was not removed. Since that operation she has given birth to several children, and they have all been girls.

Mrs. A. J. W., of Pacific Grove, California, having had four daughters, wished for a son, and according to these directions, in 1885 gave birth to a son.

Mrs. A. P., of Watsonville, California, having had two sons, wished for a daughter, and according to these directions, in 1884 gave birth to a daughter.

Mrs. H. M. S., of Santa Crux, California, had had three daughters and wished for a son. In 1883, according to these directions, she gave birth to a son.

Mrs. J. G., of Santa Clara, California, had two sons and wished for a daughter, and according to these directions, in 1883 gave birth to a daughter.

Mrs. M. J., of Fresno, California, had three daugh-

ters, and according to these directions had two sons afterward. Both of these sons were born some time during the '80s.

Mrs. K. S., of Bakersfield, California, had three sons and wished for a daughter, and according to these directions, in 1890 gave birth to a daughter.

Mrs. A. B., of San Jose, California, had five daughters, and according to these directions, in 1895 gave birth to a son.

Mrs. G. J., of San Fransico, California, wishing her first child to be a daughter, according to these directions her first child was a daughter, born in 1905.

Mrs. A. W. H., of San Francisco, California, after having been married about a year, and not becoming pregnant, was given electric treatment to her left ovary, but only to her left. She took treatment to her left ovary, after having received these directions, as the wished for a daughter. And accordingly, in 1896, gave birth to a daughter. About four years later she became pregnant again and said to me: "If your theory is true, this child will be a girl also." In due time the child was born, a daughter.

Countess H. S., of London, England, wished her first child to be a son. In 1885 I had written her careful directions concerning the law governing the determination of sex, and during the years that followed we corresponded much upon the various phases of

this theory according to her observations after my directions to her, and upon various phases occurring among my observations. For a period of two years after her marriage she observed carefully the directions for having a son, but she had no child during that time. She then gave up the idea of having a son, and lay on her left side, when she was soon pregnant, and in due time gave birth to a daughter. (See Appendix, page 251.)

This case of the Countess indicates that fertilizing spermatozoa take their direction, going either to the right or left ovary, according to the law of gravity, and not according to the nature of the spermatozoa themselves. But controlling the direction of fertilizing spermatozoa does not conflict "with the widespread principle in nature known as chemotaxis, or chemotropism."

While the above-mentioned cases do not by any means cover all those with which I have had experience by giving directions for the determining of the sex of the child according to the parent's desire, nor do they cover all of those I have observed that were examples of the operating of this law, yet they cover the various phases of the sex-determining law's operations that have during a period of thirty years convinced me of the validity of the law's operating in normal mothers according to these directions. From

time to time during this period mothers have reminded me that it was according to my directions that they had a son or a daughter, and often I had forgotten these cases entirely.

There is a case upon which I would be very glad to get data, and with which I have had no experience during these years. It is the case of a left-handed mother. It is possible that in her case the law of sex determination would be reversed, and that the right ovary would produce ova potentially female, and the left ovary ova potentially male. While that fact would neither add to nor take from the law of sex determination according to these directions, it would open up interesting opportunity for further physiological observations. (See Appendix, page 252.)

GENERAL THEORY OF HEREDITY.

It is not necessary to discuss the general theory of heredity. It has been proved, apparently, that the germ cells at the time of ripening are of equal value in heredity, that each is then a half cell, having the number of chromosomes found in ordinary or somatic cells, and that these chromosomes are the bearers of hereditary qualities. These views of heredity have been set forth satisfactorily and conclusively in *The Cells in Development and Inheritance*, by Edmund B.

Wilson; in *Heredity*, by J. Arthur Thomson, and in many other records and publications. All this, the modern conceptions of heredity, resting on intimate studies of histology and mitosis, may be taken for granted. But this theory has never claimed to show why the germ cells, apparently sexless, at the moment of the mingling of the chromosomes from the spermatozoön with those of the ovum, at once begin development as male or female. The belief is gaining ground that sex is predetermined by the nature of one or both germ cells. The writer believes that such is the case. Furthermore, she believes that the right ovary develops only ova potentially male, and the left ovary only those potentially female. Furthermore, if this is true, the fact can be made of practical value in the determination of sex. And, as a matter of fact, as already stated, it has been thus successfully used in all the cases noted above since 1880.

DETERMINING THE SEX OF CATTLE.

According to my observations during experience with cattle breeding, the law that determines the sex of cattle shows features of difference from that which determines the sex of human beings. With cattle, ova require, dating from menstruation, about four

weeks to mature. The cow's maternal ovum is matured and ovulated some hours before her paternal ovum. The exact time intervening between the maturation and ovulation of the cow's maternal and paternal ova is difficult to determine exactly, but not impossible to approximate. As a rule, within five hours of the maturation and ovulation of the maternal ovum, if it is fertilized, the product will be a heifer calf.

The manifestation of "heat" marks the maturation and ovulation of the maternal ovum of cattle. If the maternal ovum is fertilized, the paternal ovum, which matures some five hours after this manifestation of "heat," does not appear to mature. If the maternal ovum in this case is not fertilized within at least five hours after the manifestation of "heat," it disintegrates and passes away. At that period the paternal ovum is matured and ovulated and may be fertilized. But if it is not fertilized within five hours after its maturation and ovulation, it also disintegrates and passes away; then follows the menstrual flow of blood, a phenomenon which contradicts what some scientists have said, that "monkeys are the only lower animals subject to menstruation." It may be that the period of time during which fertilization may take place after the maturation and ovulation of the maternal and paternal ovum would vary with differ-

ent cattle, and according to conditions of their food, the climate, etc.

In the case of "true twins" with cattle—that is, two offspring of the same sex—so far as data has been obtained they have been perfectly normal animals.

In the case of twin calves, a cow and a bull calf, scientists say that the heifer, so far as has been reported, is always a "free-martin." (See Appendix, page 249, for explanation of free-martin.)

THE "FREE-MARTIN."

So far as data have been gathered, scientists say that in the case of twin calves of the two sexes the heifer is always a "free-martin," and barren. From my experience with cattle breeding, this abnormality among cattle is the result of the fact that cattle have two ovaries—one developing ova potentially male, and the other developing ova potentially female. Also, from the fact that the male and female ova are matured and ovulated periodically with cattle, and also, that the female ovum is matured and ovulated a few hours in advance of the male ovum; and that the "free-martin" appears to be the result and proof of the fact that the male ovum is not evolved or developed from the female ovum.

The following is from my experience in cattle breeding: After the manifestation of "heat" in the cow there was a delay before fertilization could take place that made it seem probable that the calf would not be a heifer. In due time the cow gave birth to two calves —twins—a bull and a heifer calf. The heifer was kept a number of years, but never showed signs of having a calf. And so being a twin calf and a heifer, and also barren, according to the verdict of scientists she should have been a "free-martin." The other twin calf, the bull, in this instance was a perfectly normal animal, which is also according to the opinion of scientists in the case of a free-martin twin. And according to the law of sex determination of cattle this should be the case, for the female ovum having matured, ovulated, and not having been fertilized until it began to disintegrate, would have developed an imperfect animal from the imperfect ovum; but, on the other hand, the male ovum being matured, ovulated, and fertilized before disintegration began would produce a normal male animal, as was the case.

Since the maturation and ovulation of the ova of cattle is periodic, occurring monthly, and since the time between the maturation and ovulation of the male and female ovum may be determined, therefore the sex of the offspring may be determined according to the wish of the cattle breeder.

AS REPORTED BY HUNTERS, A PREPONDERANCE OF MALE OFFSPRING OCCURS IN DRY, POOR YEARS.

The report has been made to sc entists bv hunters that there are more male than female offspring in poor years, especially in regard to the deer. If this be true, the lack of food probably affects the vitality of the mother animal, so that the maternal ovum may disintegrate and pass away before marked manifestation of "heat." And in this case of an impoverished mother animal the maternal ovum would pass quickly, the period of "heat" would pass quickly, and perhaps not very marked at that, so that the greater chance of fertilization would be with the paternal ovum.

TO THE BREEDER OF ANIMALS.

If my belief regarding the fertilization of ova be true, the following may be of practical value to the breeder of animals, cattle, horses, goats, pigs, dogs, etc. (See page 40, Chapter II.)

In the case of animals whose periods of "heat" may be observed by the breeder, the sex of their offspring may be controlled according to his wish, without too much care, according to the fact of the period and length of time of maturation and ovulation of the female and male ovum of the mother animal.

But in the case of large herds of these animals the fact of the fertilization of ova by the right and left spermatozoa of the paternal animal may be made of practical value to the breeder; that is, in case male offspring are desired from a large herd of mother animals, then the male that serves them may have the left testicle castrated. In that case the offspring would probably be only males. This could be tested by a breeder of animals, and if it proved to be the case, would be of great value. And if female offspring were desired, the sire animal or animals that run with the herds of mother animals may have their right testicle castrated. In that case the offspring would probably be females.

There are some points to be careful about in this undertaking. First, that sometimes animals are supposed to be castrated when the operation has not been thoroughly done, and therefore offspring corresponding in sex to the supposed castrated testicle may appear.

Another matter to be considered by the breeder is that it may be that the left testicle of a male may fertilize the right ovary of a female animal, and that, consequently, the right testicle of a male may fertilize the left ovary of a female animal. Before undertaking to use practically this law in nature, the breeder should ascertain whether spermatozoa from the right or left

testicle of the male fertilizes the right or left ovary's product in the mother animal. After that the practical operation of this law will be a simple matter for him to take advantage of.

The breeder of animals will no doubt be impressed with the economy of nature in the power to control the sex of the offspring of animals in either large or small numbers. In the case of a small number of animals the sex may be controlled by observing the law operating in the mother animal, and according to the directions above. In large herds of animals the sex of the offspring may be controlled by observing the law operating in the father animal, according to the above directions.

THE FUR SEAL AND FRENCH MORENO RAM.

Contributed by Dr. David Starr Jordan, President of the Leland Stanford, Junior, University, California.

REPRODUCTION OF THE FUR SEAL.

"In the group of eared seals, including the fur seal, the sea lion, and the walrus, the uterus is Y-shaped. Each horn of the uterus is impregnated in alternate years. Immediately after the birth of the young from the right side, the left side develops ova and becomes pregnant. There is never more than one embryo at

a time, which may indicate that but one ovum is present. The period of gestation is about 360 days, just short of a year. Males and females are developed in equal numbers, but there are no observations to show that the embryos in the one side (right) of the uterus are males, and in the other (left) females." (These matters are treated in detail in Dr. Jordan's *Fur Seal Investigations*, 1898.)

I do not consider that the sex-determining law as evidenced in human beings could be either substantiated or denied by any variation of it, or want of similarity to it of a sex-determining law which may be found to prevail among certain animals. But according to the above interesting observation of Dr. Jordan, it would seem almost necessarily true that the mother seals of the eared seal group do also have the two sex-producing ovaries, the one side maturing and ovulating ova potentially male, and the other side producing ova potentially female. But as to which side may develop the male or the female ova I can readily see may not be easily determined by the experimenter, especially if he depends upon deciding the matter by the nature of the sex of the offspring as found in either the right or left horn of the Y-shaped uterus, because of the habits of the mother animal and her environment, and because of this peculiar necessity in the shape of the uterus. But it would

seem that the matter could be definitely settled by taking out one ovary or the other from a sufficient number of seals to establish the law of their natures regarding the determination of sex.

FROM DR. DAVID STARR JORDAN'S EXPERIENCE AS A SHEEP BREEDER.

"Some forty or fifty years ago a writer named Sixt developed the theory that the spermatozoa of the one side in the male caused the embryo from the ovum thus fertilized to become male, those from the other side to become female.

"In 1863 a French Moreno ram named Ramsbunder was brought in to serve a flock of Dorset ewes. This Ramsbunder had but a single testis. This condition was congenital, as one of his lambs inherited the same trait. This lamb, castrated, grew up as a wether. Ramsbunder, proving an indifferent sire, his wool being too fine, was also castrated. He ran with the ewes as a "teaser," but had no progeny. This shows that the other testis, undeveloped, was also invalided. Yet among his lambs were both sexes, in about equal numbers."

Whatever conclusions as to the nature of fertilizing spermatozoa may be arrived at from this history of Ramsbunder, it must be remembered that he was an

abnormality; and any trait evidenced by his qualities as a sire might not be at once accepted as representative of the law regarding fertilizing spermatozoa in normal animals. It is my opinion that if Dr. Jordan had dissected Ramsbunder he probably would have found that his abnormality consisted in the two testes being in one side, the side he castrated, and this would have explained the fact that both sexes would appear among the lambs in question.

As to the lamb that inherited the same trait, it is known, we must remember, that sometimes in rare cases deformities are transmitted to offspring; and also it may have been, too, that this lamb's abnormality would have been found to be the fact of the two testes being found on the one side.

Dr. Jordan's citation of the experiments of Sixt, and the conclusions arising from them, is important.

MATURATION AND OVULATION OF OVA.

Among cattle this phenomenon is clearly marked and periodic, its beginning definitely marked by the manifestation of "heat," and the finish definitely marked by the menstrual flow of blood.

Among human beings the maturation and ovulation of ova is not periodic, nor is this phenomenon among them marked by any manifestation whatso-

ever. Further than the manifestation of puberty among both men and women, which marks the beginning for the possibility of bringing forth offspring, and although there is a general and usual age for this manifestation in the life of human beings, it is not absolutely fixed among all peoples, and has been known to vary by a number of years. And once the maturation and ovulation of ova begins in the maternal reproductive organs—in the ovaries—it continues, it is my belief, constantly until the climacteric period in normal women. This even can be only a general rule, as it may vary somewhat with individuals. There is no time in the month when a normal, healthy woman may not become pregnant.

The following quotation on the subject of maturation and ovulation of ova is taken from *The American Text-book of Physiology*, by William H. Howell, Ph.D., M.D., vol. ii, pp. 455, 456: "In most animals it is periodic, accompanying certain seasons, and is marked by general sexual activity. In woman and many domestic animals the relation to the seasons no longer exists. A common belief originated in the seventeenth century that ovulation in woman is a periodic phenomenon occurring regularly every month, and is contemporaneous with the menstrual flow. By postmortem examinations there is evidence of frequent coincidence of the two phenomena. But

ovulation at the time of menstruation, though probably usual, is not exclusive of ovulation at other times, for intermenstrual observations of fresh ovarian scars are not rare, and prove without doubt that discharge of an ovum may occur at any time between two successive periods." (See Appendix, page 247.)

DETERMINING THE SEX OF FOWLS.

It has long been known by fowl raisers that the shape of the egg indicates the sex of the expected chick. The pointed, slender egg hatches the cock. the fully round egg hatches the hen. Some have thought that the small egg hatches the cock. This is not the case. The small or large egg when pointed hatches the cock. By carefully observing the shapes of eggs the numbers of cocks or hens hatched may be controlled.

SEX DETERMINATION IN THE LOWER ANIMALS.

It is not essential to this theory of sex determination among human beings that it can be shown to apply to those of the lower animals whose processes of ovulation are unspecialized, or specialized in a different way. It is the opinion of the writer that no data arising from the study of protozoa, sea urchins,

insects, or fishes would have any bearing on this theory. It may be admitted that the general laws of heredity, the part taken by the chromosomes and the ovule, are essentially homologous in all animals and plants. But the specialization of the different parts of the reproductive process varies widely in different groups.

The fishes in general cast eggs and melt into the water, where the germ cells become mature. This process is not much more specialized than is that of the pine tree, which casts its pollen to the winds.

The bird ovum is fertilized within the body, and is cast off within a shell bound up with enough food yolk to maintain the embryo until the period of hatching.

The ovum of the mammal has very little food yolk, and is nourished by the blood of the mother, drawn from the uterus, through the intervention of a spongy tissue called the placenta.

In certain of the very lowest mammals the eggs are laid in a shell, as with reptiles. In others the placenta is very small, but the researches of Professor Wilson, of Sidney, seem to show that it is never wholly absent.

CHAPTER II.

METHODS FOR DETERMINING THE SEX OF HUMAN OFFSPRING—THE SEX-DETERMINING LAW CONSISTENT WITH AN APPARENT SCHEME OF HUMAN ARCHITECTURE.

WHEN THE SEX OF HUMAN OFFSPRING IS DETERMINED, AND THE INFLUENCE OF THE PARENTS, ACCORDING TO EXPERIENCE IN OPERATING THE LAW.

Science requires that a law of sex determination must establish two fundamental facts—when is sex determined, and what is the influence of the parents, the one or both. And to be of practical value, a theory of action must stand all tests all the time, or logically explain their failure to produce a required sex in the offspring. Also, as I understand the law of sex determination, there can be no question of "superiority" or "inferiority" in regard to the maternal and paternal influence in the production of offspring (Mendel). The parents' relation is always truly consortial. Determining the sex of children has to do with mechanics in the construction of the normal human body, when its organs and their functions have reached maturity.

In normal mothers the right ovary always produces ova that, when fertilized, develops as boys. The left ovary always produces ova that, when fertilized, develops as girls. And the mother determines the sex of her child when she consciously or unconsciously directs the fertilizing spermatozoa to her right or left ovary.

If the offspring of a mother is an abnormality, hermaphrodite or what not, then the offspring from the right ovary will always have the secondary physical markings of a boy. And the abnormal offspring developed from ova of the left ovary will have the secondary physical markings of a girl. For in all cases of offspring, normal or abnormal, whether single or multiple at the same birth, the sex of the child is predetermined in the ovum or ova from which the embryo was developed—the right ovary always producing paternal ova, from which boys are developed, and the left ovary producing maternal ova, from which girls are developed.

THEORY OF FERTILIZATION OF OVA.

It would seem that once it is established that the two ovaries, right and left, respectively, produce corresponding right and left ova which are potentially male and female, respectively, that the question of

fertilization of ova were not relevant to the subject. But, on the other hand, since there could not be offspring without the fertilizing influence of spermatozoa, it seems as if a sex-determining theory almost necessitates a theory of fertilization of ova. I have such a theory, but have had no opportunity for testing its validity.

It is my belief that there is a right- and left-natured spermatozoa which correspond to the right- and left-natured ova which they are to fertilize. Whether the right-natured spermatozoön fertilizes the right ovum or not I cannot say. But if it does fertilize the right ovum, it is my belief that it does not and cannot fertilize the left ovum as well. That is, that for right and left ova there are particular fertilizing spermatozoa which can fertilize only the ova which would be its complement. Whether there are right and left spermatozoa, as mentioned above, might be easily determined by experimentation, especially with cattle, horses, pigs, and dogs.

Before the fertilizing spermatozoa enter the uterus they encounter a plasmic substance, probably a secretion of the clitoris, which in appearance and consistency resembles the white of an egg; and in this matrix substance they become embedded, and are thereby easily drawn, *en masse*, into the uterus or away from it. The fertilizing spermatozoa carried

by this media that thus contain them are drawn first from the vagina into the uterus, pass through the cervix uteri, and encounter the circular fibers in the interior surface of the uterus that lead to the fibrous rings around the opening of both the right and left Fallopian tubes, as seen in Plate II. The rings appear to be made for the purpose of directing fluid to the opening of the Fallopian tubes; these openings are found in the cornua of the uterus.

Embryologists seem to agree that spermatozoa meet the ovum at or near the ovary, and that it is not possible for the ovum to be fertilized either in the Fallopian tubes or in the uterus. When the ovum is within the Fallopian tubes, which it quickly enters after being ovulated, whether fertilized or not fertilized, it is quickly covered with an albuminous layer through which spermatozoa cannot penetrate.

The above-mentioned animals would also afford good subjects for experimentation in order to discover the influence upon fertilization of this matrix substance which becomes the media by which the spermatozoa are carried into the uterus. In regard to this, it may be well to note that when a sow is spayed—that is, when the clitoris ganglion is removed and though the ovaries remain—she is made barren. And also that with the bitch, though her

ovaries are not removed when she is spayed, she is made barren.

There is another matter that it might be of value to investigate, although it need not affect either the theory of fertilization of ova or the sex-determining law of offspring. That is, to discover to what extent, if at all, the right and left cerebellum, known as the organs of "philoprogenitiveness," together with the organ of "amativeness," in both men and women, may affect the right and left spermatozoa and the right and left ova, respectively; and if the paralysis, either partial or entire, of these brain centres would in any way incapacitate the functioning of the reproductive organs in men and women. I have not encountered a human being so afflicted, nor have I had opportunity to experiment upon animals in order to investigate this matter; but it is possible that there may be found a very direct and important influence exerted upon the reproductive powers of both men and women located in these cranial ganglia.

PROBABLE CAUSE OF UNISEXUALITY IN SOME FAMILIES.

The appearance of unisexuality in families where the children are all boys or else all girls is probably due to the habits of the mother; that is, if the mother

is normal and healthy. If her children are boys, she probably had the habit of lying on her right side, in which case the fertilizing spermatozoa, or parental spermatozoa, were drawn to the right side of the uterus and to the opening of the right Fallopian tube connecting with the right ovary. In this way the right ovary would have the chance of fertilization, so that the product would always be a boy. If her children are all girls, she probably had the habit of lying on her left side, and in that case the fertilizing spermatozoa were directed to the left ovary, and its ova being fertilized, the product would always be a girl.

THE SEX OF TWINS, TRIPLETS, ETC.

The law of sex determination does not pretend to explain the phenomenon of the appearance of a number of children at a single birth, but it does pretend to show how the two sexes may appear at a single birth. According to *The American Text-book of Physiology*, by William H. Howell, Ph.D., M.D., vol. ii, p. 483, as many as five children have been born at a single birth, but what their sex he does not state.

According to my theory of sex determination, when the fertilizing spermatozoa enter the uterus, if the mother turns from side to side, with an appreciable length of time between the turns, according to the

law of gravity, both her ovaries might receive fertilizing spermatozoa, and the ova matured, ovulated, and fertilized in both ovaries would be shown by the product, whether right or left, and how many.

The sex of "true twins," that is, two boys or two girls at a single birth, indicates, according to this theory of sex determination, that ova were matured, ovulated, and fertilized, in the case of two boys from the right ovary, in the case of two girls from the left ovary. And as "true twins" are always enclosed in the same chorion and have a single placenta for both of them, this would seem to indicate that they were developed from ova produced by the same ovary, according to this theory of sex determination. This is not inconsistent with Cuénot's explanation—that because of the single chorion and single placenta for the two, therefore, they were developed from a single egg. (See page 195.)

As one Graafian follicle does sometimes contain two matured and regularly ovulated ova, according to this sex-determining law these two ova would develop two children of the same sex, either two boys or else two girls, "true twins," which are always encased in a single chorion and with one placenta for both. In the case of twins of the two sexes, the boy and the girl each has an independent chorion and placenta instead of one for both.

THE DOUBLE EGG OF THE FOWL.

According to my experience with the double egg of the fowl, they do not produce twins. I never lost an opportunity to try incubating the double egg, but they never hatched.

In the case of the human being, the ovum is fertilized after it is discharged from the Graafian follicle. And two ova from one follicle, once they are discharged and fertilized, would both have the same history in developing into a creature that one ovum would have had.

With the fowl's egg the history is different. The fowl's egg is fertilized before it receives any kind of covering, probably in the oviduct, and then receives its shell with a strong membranous lining. And probably when incubation begins in the double egg, and the two chicks require that their two vein systems be clamped into the same membranous lining, they destroy each other. The result would be, according to my experience—that is, after three weeks' incubating—that the eggs inside are spoiled.

MALE AND FEMALE GERM CELLS.

It would appear that to speak of spermatozoa as male germ cells and ova as female germ cells is misleading, if spermatozoa of the father, in order to fertilize the male and female ova, the product of the

right and left ovary, respectively, of the mother, must be the male and female complement of these ova.

It seems to me that this theory of sex determination scarcely admits the possibility of the normal father creature being unisexual or being sexless no more than it does the possibility of the normal mother creature being unisexual or being sexless, but rather it seems to declare that both the father and the mother are both male and female at the same time, since the two sexes are to appear among their offspring. And, therefore, the custom of differentiating them as male and female is not quite clear. But as higher sexual animals they are differentiated as father and mother beings, paternal and maternal.

The primary sexual characters of the paternal creature centre in the production of male and female spermatozoa and the process of impregnation, and those of the maternal creature in the production of male and female ova and the care of the developing embryo.

SPECIFIC LOCATION OF VARIOUS ORGANS OF THE BODY MAY BECOME OF SCIENTIFIC VALUE AS DETERMINING FACTORS.

It is an almost universal fact—the dextral preeminence of the right-side organs of living creatures, and this is conspicuously true of the right hand of human beings.

Is it too much to say that from head to foot the human body consists of two halves, the right and the left, which complete the whole organism? And that for the most part, especially, in organs with creative functions, these pairs of organs are of right and left location, and are differentiated by characteristic qualities.

The characterisitcs of the right and left sides in a mother's body, as I have had opportunity to observe, are identical with the temperamental requirements in the consortial union of the father and mother in the home. The hand on the right side does the important part of the work, assisted by the left hand. The right hand of a working woman almost always shows signs of having taken the burden of the work done, being larger and rougher than the left hand. Also, the right shoe of the right foot shows harder wear, and is the first worn out. Does not this show dextral preëminence of the right foot?

It would not be difficult to collect a vast amount of data both from human beings and animals which would show the right dextral preëminence in various organs of their structures. On the other hand, the left side is the conserver of the body's life forces.

The left hand and foot, not having dextral preeminence, are used as balance to the right hand and foot, which go forward first. Is it not demonstrable that the natural strenuousness of the body is in the

right side, and that because of this the right side of the body becomes the natural protector, as it were, of the left side, in which is located the heart?

A woman in danger of falling while walking will naturally relegate to her left hand whatever she may be carrying, because of the natural instinct of the right hand's protection; and for the same reason a man takes a woman on his left arm, leaving the right hand free for defence.

It has been my observation that an overworked mother will suffer depletion of strength in her right side first, which is perhaps due to this conspicuous and natural dextral preëminence of the right side of the body.

It is a traditional fact that masculinity is connected with the idea of right-handedness, and that femininity is connected with the idea of left-handedness.

It may be observed that the right and left cerebellum have a direct influence upon the right and left reproductive organs in both men and women. In this case in a left-handed woman the sex-producing ovaries may reverse the nature of product, and a boy might be developed from the ova of the left ovary instead of from the right. But this would not be necessarily true in left-handed women. But it is an interesting phase of the sex-determining law to investigate.

CHAPTER III.

TELEGYNY.

A NEW THEORY OF HUMAN HYBRIDIZATION INDICATING THE INFLUENCE OF A DISTANT FEMALE —THIS MUST NOT BE CONFOUNDED WITH WEISMANN'S TELEGONY, THE INFLUENCE OF A DISTANT MALE.

Dr. J. Arthur Thomson, in his work on *Heredity*, page 143, says, under the head "Telegony and Other Disputed Questions:" "The term telegony is applied to doubtful, certainly rare, but, if true, very remarkable cases where an offspring resembles a sire which, though not its father, had previously paired with its mother. More theoretically expressed, telegony is the supposed influence by a previous sire on offspring subsequently borne by the same female to a different sire. The ovum or embryo is supposed to be influenced by the mother's previous impregnation or by the consequence thereof.

"To take a simple instance, the racehorse Blair-Athol had a very characteristic blaze or white bald face, and it is said that mares which had once borne

foals to Blair-Athol subsequently produced to quite different stallions foals which exhibited the Blair-Athol blaze. Now it is very generally asserted by dog breeders that if a thoroughbred bitch has had pups to a mongrel her value is greatly decreased, for she will not afterward breed true.

"The alleged phenomena are of much interest, but the evidence of their actual occurrence is far from satisfactory, and their theoretical interpretation in terms of telegony is beset with physiological difficulties. But as a belief in telegony is still widespread, it will not be unprofitable to consider (*a*) the alleged facts, and (*b*) the interpretations suggested."

The following are some of the data and conclusions included under Dr. Thomson's (*a*) and (*b*), as mentioned above. On page 149 he says: "The position of affairs being that as a number of great authorities, *e. g.*, Darwin and Spencer, had expressed their belief in the occurrence of telegony, and that an equal number of competent authorities had expressed themselves extremely skeptical on the subject, Professor Ewart resolved on definite experiment—the only secure path."

And as a result his verdict was:

"That the evidence of any undoubted telegony is very unsatisfactory.

"That telegony does not generally occur, even

when what were considered to be favorable conditions were secured; indeed, anything suggestive of telegony occurred in only a very small percentage of cases. Moreover, where peculiar phenomena of inheritance were observed, they seemed to be readily explicable on the reversion hypothesis."

On page 155 he says:

"Somewhat subtler is the suggestion—often also called the 'infection hypothesis'—that although the sperms of the first sire cannot be supposed to persist and fertilize ova discharged long afterward, yet it is conceivable that the disintegrated substance of the sperms may persist and influence the ovaries and the ova, or that the sperms may exert an influence which does not amount to fertilization. So great a physiologist as Claude Bernard seems to have believed in the possibility of such an influence.

"Another slightly different suggestion is that the surplus sperms derived from the first sire exert a physiological influence on the constitution of the mother, such that subsequent gestations are affected.

"Perhaps the most plausible theory is that the mother is influenced through the fetus during pregnancy, and that the influence reacts on subsequent offspring. On this so-called saturation hypothesis the suggestion is that the characters of the sire while expressing themselves in the unborn embryo, also satu-

rate into the dam and affect her constitution in such a precise way that her offspring by subsequent sires may, through maternal influence, acquire (or inherit) some of the characteristics of the first. Thus, Sir William Turner, in 1889, in discussing Lord Morton's classical case of the mare, says: 'I believe that the mother had acquired during her prolonged gestation with the hybrid the power of transmitting quagga-like characters from it, owing to the interchange of material which had taken place between them in connection with the nutrition of the young one. In this way the germ plasm of the mother, belonging to ova which had not yet matured, had become modified while still lodged in the ovary. This acquired modification had influenced her future offspring, derived from the germ plasm, so that they in turn, though in a more diluted form, exhibited zebra-like markings.'

"It is conceivable that something like the 'saturation' above indicated may occur in a case of a poison or protective antitoxin which might diffuse in and out. We can imagine that a sire infected with some virulent disease, and showing certain structural disturbances associated therewith, may have offspring which are similarly affected, and that the influence from them may pass before their birth into the constitution of the mother, and so affect her that subse-

quent offspring by a healthy sire are diseased after the manner of the first.

"But while we have some facts to go upon in regard to the diffusion of toxins and antitoxins, we have none as yet which justify us in supposing the diffusion of structural characteristics or of representatives of these.

"Apart from stock, the belief is often expressed in regard to man himself: 'We certainly know that what used to be spoken of as the "infection germ," but which, following Weismann, we nowadays call "telegony," was considered possible by physiologists at the end of the seventeenth century; we know the infection tradition has long influenced Arab breeders, and that believers in the hypothesis may now be found in every part of the world, more especially where an overlapping of distinct races occurs.'"

On page 163 he says, under Maternal Impressions:

"It is a time-honored belief that the mental states —especially vivid sense impressions and strong emotions—of a pregnant mother may so affect the unborn offspring that structural changes result which have some correspondence with the maternal experience. The belief was hardly doubted until Blondel began to criticise it early in the eighteenth century.

"Everyone allows that the mother's health in the widest sense may react on the offspring, within what

limits we hardly know; but it is a very different matter to believe in definite and specific structural effects. There can be no doubt that the firmly rooted theory is in the main quite unscientific, except in the sense that it expresses the instinct to discover some cause for peculiar phenomena. A child has hypertrichosis: did not the mother look too long at a picture of John the Baptist in a hairy robe? A white mother has a dark child: what can she say but that she was frightened by a Moor? The abundant literature has been carefully studied by J. W. Ballantyne, and it need hardly be said that his general verdict is wholly against the tenability of the theory, except in a very refined form.

"The mental experiences of the mother have been held to explain peculiarities of color, abnormal hairiness, birthmarks, malformations, and even conception itself. It is admitted that shock and distress and the like may have prejudicial effects on the unborn child. But to associate a particular structural defect with a particular mental impression seems an untenable position. Sometimes, indeed, the mental impression theory is demonstrably untenable when the impression occurs la e in pregnancy, for most of the great events in development occur very early. At the same time, it is always unwise to speak of impossibilities in regard to matters which are inade-

quately known and imperfectly understood. That we cannot imagine the nature of a physiological nexus does not prove its non-existence. Thus, as in regard to the transmission of acquired characters and 'telegony,' we may be scientifically skeptical and give a verdict of 'non-proven' without dogmatically saying 'impossible.' We must remember that for a prolonged period the unborn child is part and parcel of the mother—almost an integral part of herself—and we are beginning to know enough of the influence of mind upon body to make us cautious in dogmatizing as to the possibilities of what Ballantyne finely calls 'the mysterious wireless telegraphy of antenatal life.' "

TELEGYNY AND MATRIX PLASM.

At the first writing of the subject matter of this book, the law of sex determination, during the year of 1907, I expressed in no uncertain terms my belief that the maternal parent also contributes a particular substance to the fertilization of her ova. But as the presence and influence of this substance was a by-product finding through investigations and observations by which I hoped to establish, at least, the plausibility and probability of the sex-determining law as I understood it, I submit my theory regarding

it for experimental investigation and also suggest the word matrix plasm as a suitable name for that particular substance.

I choose telegyny as a word form corresponding to telegony to express a similar idea, telegony meaning the influence of the first male on the succeeding births of the female; telegyny in the same way I suggest as a word to signify the influence of a previous female upon the male transferred through the influence of matrix plasm.[1]

However, as tele in Greek means distance, and gyny means woman. If telegony means the influence of a distant male, telegyny may be taken to mean the influence of a distant female. Therefore, I suggest telegyny to indicate this particular phase of human hybridization resulting from the influence of the matrix plasm of another woman besides that of the mother's upon the paternal spermatozoön before it fertilizes the mother's ova.

[1] Dr. A. Rose, the authority in this country on modern Greek and on English words derived from the Greek, says: "The meaning which we attach to telegony is arbitrary, like the meaning which we give to psychosis, atony, dilatation; and telegyny reminds me of the small boy who translated, Alexander magnus natus est in absentia parentis sui, with, Alexander the Great was born in the absence of his parents. If we wish to infer by telegony influence by a previous male we have to say so."

PRODUCTION OF MATRIX PLASM AND FERTILIZATION OF OVA.

It would be well to read the following in connection with an illustration showing the cord, fiber, and filament connection between the cerebellum and genital organs in both men and women. After the generation of the male and female stimuli in the cranial ganglia at the base of the brain in the back of the head, known as the organs of Philoprogenitiveness and the organs of Amativeness, of both maternal and paternal parents, then analogous to the law of crystals, the paternal male and female spermatozoa (germinal matter) may unite with the maternal male and female matrix plasm, thus forming new spermatozoa, the parental spermatozoa, and which go in rapid, eager search for the fulfilment of their destiny, which is to fertilize the ovum.

This is one of the respects in which my theory of fertilization of ova differs from all others. That is, that the maternal parent's cranial ganglia, located in the back of the head, also produces stimuli whose destiny is the generation of male and female matrix plasm and which is necessary to the process of fertilization of her ova. Also, as I have undertaken to show above, it appears to me probable that this matrix plasm is the vehicle for the transmission of

the maternal hereditable characteristics. As I have said before in this book, if the gland which secretes this matrix plasm is removed, fertilization cannot take place, and the maternal creature is thus rendered barren, though she may have healthy, normal ovaries and uterus. Hence my belief regarding the maternal contribution to the fertilization of ova.

A FEW EXAMPLES IN EVIDENCE OF TELEGYNY AMONG HUMAN BEINGS.

Telegyny, or the new phase of human hybridization which came under my observation in connection with investigations concerning the sex-determining law, is the inoculation of spermatozoa by matrix plasm and the probability of this spermatozoa so infected fertilizing ova, and which is consistent with the length of time spermatozoa may retain their vitality according to the discovery of Bossi, which was about fourteen days. It may be that the mingling of matrix plasm with spermatozoa, which is the union of the maternal and paternal male and female principles of life, makes Bossi's supposition possible. However, this need not be the reason for the continued vitality of spermatozoa. Nor does telegyny depend upon Bossi's belief entirely. For as plants

are hybridized by the pollen dust from various other plants carried by the legs and wings of insects, matrix plasm of another woman may also be carried to the parental spermatozoa destined to fertilize the mother's ova, and thus hybridize the offspring of such parents.

This quality of the matrix plasm need not interfere with the matrix plasm's influence upon the fertilization of ova. I maintain that fertilization of ova cannot take place without the influence of this substance secreted by the maternal clitoris gland upon the paternal spermatozoa, after which ova may be fertilized. For if the gland which secretes this plasm is removed, fertilization cannot take place.

The first time I had my attention attracted to the possibility of this phase of human hybridization was when noticing that a pumpkin vine growing near a watermelon vine spoiled the watermelons. This was evidently due to the fact that the minutest particle of pumpkin pollen dust would affect in its fertilizing quality the watermelon egg cell. Indeed, it is a well-known fact that fruits and vegetables are affected, especially as regards taste and color, by the presence among them of other fruits and vegetables and flowers; and that these qualities in taste and color, foreign to the original fruit and flower, evidently are the result of nature's various ways of fertilizing them

by winds, by the legs and wings of roving insects, and so on. Then if hybridization among plants is affected by the faintest particle of their fertilizing dust, must not also the transmission of the faintest particle of hereditary bearing substance among human beings affect also human hybridization? With this notion I began observations of human beings, and, as far as it was possible, got the story of the birthplace of children, the habits of their parents, and the people among whom they found themselves, which might have an effect upon these children. Facts that appalled me began to manifest themselves in these records, which had explanation, apparently, only in the laws of hybridization implicated or involved in the processes of fertilization of the human ovum or egg cell.

But this human hybridization depended upon the possibility of grafting into the offspring of a given father and mother the qualities belonging to another woman whose race, being entirely different from that of the child's parents, was more or less easily discernible and traceable. This form of hybridization could only take place by the inoculation of the father's spermatozoa by the matrix plasm of this other woman before the fertilization of the ovum of the child's mother.

This transmission of maternal hereditable qualities

would explain the mystery which cannot intelligently or scientifically "associate particular structural defect (or effect) with a particular mental impression," as set forth both in the case of the lady whose child was born with the qualities of the Moor, as cited above, and who could say nothing as to the phenomenon, and also in the mysterious case quoted in *Zoönomia*, by Dr. Erasmus Darwin, on page 412, of the striking resemblance of the child of a certain man's wife to the woman upon whom that man had thought so much, and who was not his wife.

And it is a conspicuous fact that it is to the virtuous mother such a hybrid may be born. Very naturally, if a mother were also promiscuous in living with different men, as well as the husband with different women, their offspring, in case there were any, would become a sort of composite of the people of their environment, and not be the offspring, pure breed, of the husband's and wife's father and mother and their ancestors.

There is no mystery whatever connected with this hard-and-fast law operating in the properties of the matrix plasm, and it is easy of demonstration.

This supposition will illustrate what I mean. Suppose a Mormon, a white man, had two wives, one white and the other black. The white wife would in all probability give birth to children some of whom

would be strongly marked with the type of the black wife. These children so marked with the type of the black wife would be the result of human hybridization attained by the transference of matrix plasm from the black wife to the father's fertilizing spermatozoa, and which fertilized the ovum of the white wife, and these markings of the black wife in the children of the white wife are a simple case of inheritance, attained by the influence of the matrix plasm of the black wife. If a fair, flaxen, Saxon woman were the wife of a man who also had a harem of African wives, Japanese wives, Chinese wives, Moorish wives, Hindoostan Indian wives, American Indian wives, Arabian wives, or any other distinct race and type among his collection, or women among them that were in any way degenerate, especially morally, the children of his Saxon wife would very likely present from time to time, at least, striking resemblances to these various types. Their children would not be and could not be a "true breed."

I have seen such children of parents that had the markings of the foreign race to the extent of almost "half breed." This would account for the degeneracy of children of parents when this could not otherwise be explained.

It also affords a scientific basis for the explanation of marked resemblances which are sometimes seen

in the children of parents of a given nationality when their children are born in foreign countries, and whose race their children resemble.

According to this theory of human hybridization, it would appear that the striking resemblance which occurs, not infrequently, of children foreign born to the natives of the country where they are born is not due to the peculiar atmospheric conditions of the country, nor to its food, nor its topography, nor to any scenes whatever that the mother may have looked upon or thought upon, nor because of any fright the virtuous mother may have suffered during pregnancy by the imposition of the unexpected presence of one of the natives of that country. But the resemblance in color, even feature and temperament, of such children is due to the law of the transmission of hereditable maternal qualities through the matrix plasm, and in this case, of another woman than their mother, transmitted by the paternal spermatozoa in the process of fertilization of that mother's ovum.

According to this law of human hybridization, parents, especially fathers, will be able to definitely locate unexpected and otherwise unexplainable qualities, even structural, that appear among their offspring.

Some of the more striking examples that have come under my personal observation are the chil-

dren of American and English parents, fair-haired, fair-skinned, whose children resembled, to the point of half-breeds in some cases, the native Hawaiians where their children were born. The resemblances were manifested in physique, in complexion, in texture of skin, and in temperamental qualities. In one case the father of the English children had the habit of long tramps among the habitations of the natives, remaining among them weeks and even months at a time, during the years that the children of his family were being born. At last he gave himself up to living among the natives to such an extent that he contracted leprosy, and finally vanished from the presence of his family entirely. The wife of this man was a high-minded Christian woman of noble soul and pure life.

There was another remarkable case of the child of an American family. The father was a high official. Native Hawaiian women were numerous as domestics on his place, and a daughter born into that family during that time was strikingly Hawaiian, and might have been taken for a half-breed.

And there is the classical example of the fair English parents whose child, being born in India, was a striking example of Hindoostan Indian in appearance. There were many cruel and pitiful tales told with regard to the surprised mother, who knew her heart

and life were virtuous and loyal to her husband. If that husband had known this law of human hybridization he would also have known in his heart that the child was so marked not because of any mental impression of the mother, and that she need not at all have been chased by the Indian in order for their child to be grafted with the foreign type, but that he himself had, according to the subtle laws of inheritance, inoculated their child with the Hindoostan woman's blood and race.

True records and observation added to actual demonstration are possible means of verifying this law of human hybridization by means of the matrix plasm, transmitted by spermatozoa in the process of fertilization from a woman of one race to the fertilized ovum of the wife, who may be of another race.

And so matrix plasm appears to be the vehicle of legitimate and not illegitimate maternal ancestral inheritance in offspring, while the fertilized ovum is the means of preservation of species in the broadest sense by heredity, by which it might be said is maintained the immortality of the paternal and maternal germ cell.

In Abbot Mendel's observations regarding plant hybridization may be found a basis for this theory of human hybridization. This theory necessitates

the manifestation of other influences brought to bear upon the ovum, or seed cell, besides that of the paternal, or father's, spermatozoa.

Mendel says, as will be remembered from the quotation made from his work on page 115: "It is immaterial, as regards the form of the hybrid, which of the original species is the seed cell and which the pollen parent. If the influence of the egg cell upon the pollen cell were only external, if it fulfilled the role of 'nurse' only, then the result of each artificial fertilization could be no other than that the developed hybrid should exactly resemble the pollen parent, or at any rate do so very closely. Among the offspring of the hybrids both the original types reappear in equal numbers, and with all their peculiarities."

This observation of Abbot Mendel's appears to substantiate the law of sex determination, as I understand it, in that the maternal and paternal parents do not reproduce themselves in the determining of the sex of their offspring as individuals, but only as species. Also, that the maternal parent has a part in the fertilization of the egg cell which is produced in her ovaries aside from the fact of the reception of the fertilizing spermatozoa produced by the paternal parent. Otherwise, her part in the production of offspring might be considered as a passive one, or as that of "nurse's" for the life-giving, creature-

creating, paternal spermatozoa. But observation does not substantiate this, nor does Abbot Mendel's experiment on peas bring him to that conclusion.

If it is true that the egg cell, or ovum, is passive in its nature, that it does perform the nature of nurse only to the developing fertilized ovum; and also, if it is true, as is generally supposed, that paternal hereditary qualities are transmitted by the sperm cell or paternal spermatozoa, then, in order for the offspring to resemble the mother and also her generations, the contribution of hereditable qualities must also be transmitted by her in a similar process to those of the father parent. And so it would appear that maternal hereditable qualities are transmitted by the matrix plasm, as patrix plasm (spermatozoa) transmits hereditable qualities of the paternal creature. And, also, that among vegetables, fruits, flowers, there is, no doubt, the matrix dust which mingles with the pollen cell, or patrix dust, at once accomplishing fertilization and hybridization for those forms of life. And so it would appear that by the mingling of the matrix plasm and patrix plasm, of matrix dust and patrix dust, the offspring of animals and plants resemble their ancestors, immediate and remote. And that, also, it is through these media that the processes of perfection in the development of pure breeds in animals and plants are attain-

able as well as through these media their degeneration is accomplished. And that by the processes of fertilization of the ovum and seed cell by the parental spermatozoa and fertilizing dust the preservation of that species is accomplished in the possibility of the reproduction of both paternal and maternal animals and plants from the mother creature and mother plant.

BIRTHMARKS AND THE MOTHER'S MENTAL IMPRESSIONS.

There is mystery enough connected with the "longings" of a pregnant woman, and the traditional "she is not herself," to suggest the presence of miracles—which we call happenings whose beginnings and end we may not preceive—rather than the manifestation of laws natural to our physical beings. And who can account for striking resemblances between people who are not blood relatives? Or that there are countries whose men inhabitants, especially, and often the women, are as much alike in looks as the peas in one pod. Or that there are eras of time when the spiritual and mental qualities of the peoples of that time of all countries resemble, often the physiques of the men and women showing striking likenesses, though such people are separated by seas and conti-

nents. Sometimes this has appeared as highly developed mentalities and a superior spirituality; but, again, this phenomenon has appeared among people who exhibit a curious likeness in degeneracy.

The habit of speaking of certain periods in the history of the earth's inhabitants as an age of poetry, an age of unusual religious awakening, an age of exploration, of invention, of art production, and so on, is well known. And yet these all may be the result of a natural law by which the human organism naturally seeks expression.

Who has not met strangers in strange countries who bore striking resemblance to acquaintances at home? Indeed, if the same individuals had been met at home, though they were strangers, they would have been addressed as acquaintances, so great was the resemblance. On the other hand, twins are sometimes born as unlike as an apple and an oak ball.

Can this be explained at all? Or by what physical law do we grow to resemble, to actually resemble, those we think upon in love and admiration? It is not at all uncommon for devoted, loving, loyal husbands and wives, after years of life together, to resemble each other in feature and expression as much as though they were born sister and brother. Is there any matter in this fact for telegony?

Is there some subtle, actual physical law at work,

playing out into the infinity of our beings and of which these conditions are the natural result, or are they due to the workings of "the mysterious wireless telegraphy" spoken of by Ballantyne? But who has sight so keen and true that it can follow the imprinting of such material facts by the processes of immortal flashes and vibrations? And there I must cease.

And birthmarks, "in which there is a widespread belief"—Would cameraless photography occurring during the pregnancy of the mother be responsible for these unexpected occurrences? And if it did, who could analyze it?

Verily, "the fathers have eaten sour grapes and the children's teeth are set on edge." And sometimes it would appear that the mothers especially had so eaten.

If reports be true, birthmarks may be skin spots, deficiencies in powers of digestion and assimilation, as abnormal desires supported by extra digestive and assimilation powers; also, sometimes, as habits of gesture, and sometimes little mannerisms of speech and actions, sometimes as unusual states of mind, such as supersensitiveness regarding odd things, and so on. I knew a mother who, during pregnancy, was obliged for a certain continuous time to eat sheep's flesh. She took such a sudden abhorrence and distaste of the meat that she only ate it rather than go

meat hungry. After the birth of her baby she recovered from this spasmodic distaste of this particular meat. But the child from its first meat-eating days could not endure the smell or the taste of the sheep's flesh. Whenever the child attempted to eat that meat, the result was always the same—indigestion and want of assimilation, and usually attended with acute indigestion cramps. Was this a birthmark?

Another pregnant mother's particular "longing" was for mackerel. Her baby was born with what seemed to be the outlines, in a brownish color, of a mackerel on its side, and which design never faded in after years, and the child's ability to eat and digest mackerel was more than normal. Was this a birthmark?

The "longing" of another pregnant mother was for brains to eat. This was provided for her. But as she was slowly approaching the dish of deliciously prepared food, quivering with delight and with the eagerness of a child to be eating it, a cat sprang to the plate and before she could prevent it ate the brains and licked the plate clean. She wept as a child might have done, and was as unhappy and brokenhearted over this fate of the brains food for which she had waited with such keen anticipation of satisfaction as a little child might have been. Shortly after that the little baby was born, and upon one of its shoulder-

blades was a representation of the mess of brains, designed in brownish outlines, and which did not fade as the child grew up. Was this a birthmark?

Numberless such cases might be recorded, as also those where a parent may possess a talent which it has become the inmost desire of that parent's soul to put into expression, but in vain. But on the birth of a child the talent appears as brilliant genius, which may even manifest itself in miraculous perfection in the offspring while yet an infant in years.

There lived in a little house in the midst of a flower garden, that in its turn gave into a wide-spreading orchard, a loving and loyal husband and wife with their first born child. The wife was now in the first months of pregnancy with her second child. Their nearest neighbor was a Mexican family, among the members of which was a dashing young man of about twenty-two. He and his sister and mother were frequent visitors to this little household of three. But the young Mexican was the most frequent, and the husband's being home or not did not disconcert him. Men of affairs must need spend morning hours, and sometimes afternoon hours too, inside of offices, but wealthy and aristocratic young Mexicans rode horses all day, decked out with silver, leather, and velvet trappings, both horse and rider. It was this lady's custom to walk much among her flowers and fruit

trees. And it became the custom of this young caballero to suddenly appear before her during these promenades. Her startled eyes would no sooner perceive the vision of his blazing, dark eyes fastened upon her, than by one pretext and another she made him understand that he was dismissed, and would herself retire into the house. When she would be about to open a gate, suddenly and unexpectedly the young Mexican would appear on the other side and with gracious suavity open the gate, always his passionate, dark eyes upon her, though his words were reserved and polite. If the husband were present, it was still the same. By every means possible he would prolong his stay.

One summer day this lady was lying on her couch on the veranda, sleeping, her eyes covered over. At that time she was having an eye malady that was epidemic in that part of the country. She heard footsteps approaching, but did not disturb herself, as she supposed it was her husband. After some time she suddenly threw off the covering from her face, and there to her astonished eyes stood the young Mexican, intensely looking down upon her with deep concern. At that moment the husband arrived, and the young man told him of a weed growing in that locality that he said would cure the eye malady. It grew in a cluster of stalks, some two feet high, shoot-

ing up from one root. It had large, soft leaves, that somewhat resembled the leaf of the milk-weed, and a star-like flower, white petaled, with a yellow centre. Its corolla and heart were disposed somewhat after the manner of the sun flower. When the leaves of this plant were crushed there oozed a yellowish milk; with about a half-dozen applications of this milk to the sore eyes they were healed.

After that the young caballero would ride up and down, Mexican fashion, in front of the house, drawing rein whenever he could get a glimpse of the lady or a word with her. This never failed to annoy her, and also to strike a sudden, sharp terror into her heart. Always his appearance was most unexpected, and always accompanied by the wrapt, passionate, dark gaze. Though he was a most clean-souled young man.

Afterward, when the baby was born, one of the child's eyes was marked by the color and fire of the dashing Spaniard's eyes, while its other eye was a calmish blue-gray eye. This was all the more remarkable as neither of the parents of the child had such eyes. Was it a case of maternal impression?

Upon investigation I found that the grandparents of the baby's mother had just such eyes as the baby. The grandfather's were big, dark, flashing eyes, and the grandmother's the mild, blue-gray eyes. So

"bang!" went the theory of mental impression, and in its place came the physical law of reversion.

Dr. J. Arthur Thomson says: "For a prolonged period the unborn child is part and parcel of the mother, almost an integral part of herself."

Mothers know that during pregnancy they are swayed by another personality than their own, and probably by the child's, which manifests its nature early. Because of this during that important period she may become childish, especially regarding food. Indeed, any kind of uterine illness or pregnancy immediately affects the maternal creature's entire organism, and is especially conspicuous in the face. This indicates the sensitiveness of the maternal organs and their immediate, sympathetic connection with the brain and the rest of the body. As a matter of fact, the uterus and ovaries receive from a mass of veins, filaments, and fibers tribute from all the rest of the body, the supply media being especially located at the hilum, where the large convoluted veins form a sort of vascular bulb.

A pregnant woman knows she must endeavor to control the childish whims and impulses that possess her, especially not giving way to indignations, or violence in act or thought. And this, if not for her own sake, at least for the sake of her unborn child, who will surely be marked by the overdevelopment

in the qualities of her uncontrolled passions. And, I take it, it is really the child's personality swaying her. Thus, it is in the womb that the mother begins to discipline her child for love of it yet unborn, and by a sure self-control.

Those who make up the household of a pregnant woman owe it to her to more especially love and cherish and nourish her at that time; to grant, and with despatch, all of her healthy, normal, harmless "longing," and to surround her with every comfort and happiness possible. For it is during those days that the future generations are being moulded for the possibility of being instruments of good or evil. Those terrible, mysterious days of pregnancy. If a mother is overworked at that time—if, indeed, she works at all, and her vitality is impoverished, she may not be able to supply the normal amount of "liquor amnii" for the developing embryo, and because of this the child might become crippled structurally.

Children born to a normal, healthy, beloved, and loving wife and mother have the very greatest chance to become valuable and happy additions to the great human family.

CHAPTER IV.

SOME MATTERS ADDRESSED ESPECIALLY TO WOMEN.

If a mother wishes for a girl, and continues persistently to remain on her left side for a few hours after the presence of the fertilizing spermatozoa in the uterus, but especially refraining from lying on her right side for at least twelve hours, then if she has no child her left ovary needs treatment. Sometimes an electric bath will restore the natural health to a dormant ovary. After the electric treatment, and if she carefully follows the above directions, if she is normal she will surely give birth to a girl baby.

If she wishes for a boy, and does not have a child after remaining on her right side for a few hours, but especially not lying on her left side for at least twelve hours after the presence of the fertilizing spermatozoa in the uterus, then her right ovary needs treatment. After that a normal mother, if she follows carefully the directions given above, will surely give birth to a boy baby.

If a mother after following the above directions for having a boy or a girl baby, as the case may be, for, say, any reasonable length of time, has no

child at all, she should at once have medical treatment.

In the case of ovaries that are supposed to have been removed, mothers must remember that it is a well-established physiological fact that the slightest part of an ovary not removed in such a surgical operation may mature and ovulate its ova, and that therefore with fertilization a child might be born of the sex corresponding to the supposedly removed ovary.

When an ovary has been removed, so far as I have had opportunity to observe, no child has ever been born with the sex corresponding to the removed ovary.

Because of the dextral preëminence of the right side of mothers, an overworked mother will suffer first in her right ovary. From too hard work her right ovary might be incapacitated to such an extent that she could not give birth to a boy at all. And if she is able to give birth to a son, there are many chances that he will be a degenerate physically, and small chance for him to be normal in strength.

On the other hand, an overworked mother, because of the natural protection afforded the organs on the left side of her body, may give birth to girls principally. And these girls may be normal and superior in strength to the sons of the same mother.

And because of the greater strenuousness of the organs in a mother on the right side, as compared to

those on the left, an overenergetic woman, for any reason, during childbearing is likely to give birth to children degenerate in physical strength, and in normal mothers the boy babies will be the first to be so affected; the children of such mothers are sometimes even deformed when there is no other reason apparent for such a calamity.

During pregnancy, the rule for mothers is not to overexert themselves, and at the same time some exercise is healthy; they should in this regard observe the "golden mean."

It may happen that a physically weak mother, especially if her environment is favorable, brings forth strong, healthy, normal children, both boys and girls, while in a like environment large, fat women sometimes give birth to weaklings, both boys and girls. Many interesting and striking examples of these cases have come under my observation, but their history could not be included here.

During pregnancy a woman should avoid certain activities altogether, such as sewing by hand, or running a machine by the feet or hands, beating or threshing movements with the arms, and any work that requires the lifting of the arms up and down in reaching above the height of the body; also, she should avoid pushing any object with the foot. These various activities at such times are supposed

to be the cause of babies being born with the umbilical cord around the neck, which is often the case, especially when mothers have used the hands and arms a great deal, as has just been described. Such children are usually afflicted, from this fact of the umbilical cord, with stammering and stuttering, and with girl babies it not infrequently results in chronic hysteria, when otherwise there would be no explanation for these calamities appearing in the children. I do not mean to infer that the appearance of the umbilical cord wrapped around the neck of a baby is the only cause for those nervous difficulties, but that they do almost invariably accompany this displacement of the umbilical cord.

HORSEBACK RIDING.

Too frequent horseback riding, and especially sideways, might make it impossible for a woman to give birth to a child. This would be the result if the neck of the uterus became so displaced that fertilizing spermatozoa could not enter it. However, this difficulty might be corrected by a physician, yet the mother in question might not be able to have a son. Riding sideways, either upon a woman's or a man's saddle, necessitates a cramped position of the right ovary, and might render it incapable of healthy,

normal maturation and ovulation. Riding astride is the healthiest position for women.

There was a young woman who from childhood had ridden sideways. She was obliged to go on horseback to her school, and after her marriage she did not have a child. Some few years afterward, upon medical examination, it was found that the neck of the uterus was so badly displaced that fertilization could not take place. Her physician accomplished successfully the delicate and difficult operation of straightening this organ. She soon became pregnant, and in due time gave birth to twin girls.

There were two daughters of a ranchman, the two eldest of a large family of boys and girls, who were accustomed to "run cattle," riding their mustangs with a man's Mexican saddle—that is, a saddle with a high tree. They rode these sideways. Though they were otherwise strong, healthy women, when married they neither one had children. And though they were married the second time, still they had no children.

There were two other young women who had ridden horses, and also sideways, all their lives. After their marriage they asked me for my directions for having a son. And though they followed these directions carefully for a length of time they had no son. But upon following the directions for having a girl, they

both gave birth to girl babies. This made me think that their horseback riding had made it impossible for them to have a boy.

ATHLETIC WOMEN.

When athletics are too continuous and too violent the woman's maternal organs may be displaced and injured. When athletic women, who may be apparently healthy and normal, do not have children, this seems to be the only explanation of their difficulty.

The most striking case of this kind I ever encountered was that of a young girl whom I knew from her infancy. She would outdo her brother in all athletic feats—running, leaping, climbing, high kicking, turning double somersaults, etc. After being married for a number of years she had no children. Upon examination her physician found that the neck of the uterus was completely turned away from its normal position. In his attempt to straighten this the young woman lost her life, though the same physician had performed the same operation successfully upon other patients.

FACTS REGARDING THE PHYSIOLOGY OF THE MATERNAL REPRODUCTIVE ORGANS.

The accompanying plates and facts are given for the benefit of women who may not be familiar with the physiology of these organs.

The following facts concerning the physiology of the maternal organs of reproduction are taken from *An American Text-book of Physiology*, vol. ii, edited by William H. Howell, Ph.D., M.D., and selected especially from the paragraphs on reproduction in that volume written by Frederick F. Lee, Ph.D.:

"Sexual organs are classified into essential and accessory. The essential organs are the two testes of the male and the two ovaries of the female.

"The accessory organs of the female comprise the oviducts, or Fallopian tubes, the uterus, the vagina, the various external parts included in the vulva, and the mammary glands."

THE FEMALE REPRODUCTIVE ORGANS.

"The female reproductive organs have as their specific function the production of the essential female germ cell, the ova, and their transference to the uterus, and to the outside world if the ova are unfertilized. Other specific functions are the protection and nutrition of the developing embyro, its ultimate transference to the outside world, and the nutrition of the child during early infancy."

THE OVARIES.

"Ovaries are often spoken of as glands, but they are not glands according to the ordinary histological and physiological use of the term. They are solid organs, with a structure peculiar to themselves, and their function is the production of ova.

"The ovaries are the true distinctive female organs in which alone the female elements, the ova, can be produced.

"The Fallopian tubes and the uterus are accessory in their use, the ovum, or the female element passing through the tube to the uterus, where it forms the attachments to the mother that are necessary to its nourishment and full development.

"The ovaries lie nearly horizontal in the pelvic cavity, on either side of the uterus.

"They are whitish in color and their form ovoid and flattened, with the anterior border, sometimes called the base, attached to the broad ligament.

"The ovary is about an inch and a half in length, half an inch in thickness, and three-quarters of an inch in width at the widest portion.

"The outer extremity is somewhat rounded, and is attached to one of the fimbriæ of the Fallopian tubes. The inner extremity is more pointed, and is attached to the uterus by means of the ligament

of the ovary, which is marked, 7 7 the hilum. (See Plate I.)

"The ovary receives bloodvessels which penetrate at the hilum. They are large and convoluted, especially at the hilum itself, where there is a mass of convoluted veins forming a sort of vascular bulb.

"On making a section of the ovary, it is readily seen with the naked eye that it is composed of two distinct structures—a cortical substance, sometimes called the tunica albuginea, and a medullary substance, containing a large number of bloodvessels.

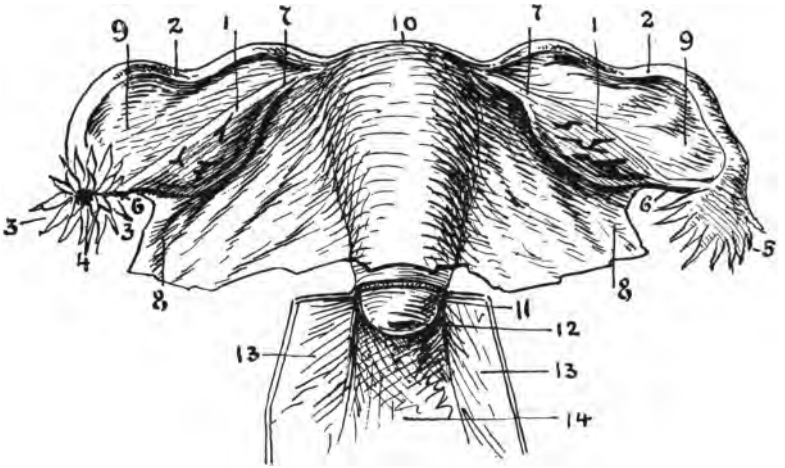
"The cortical substance alone contains the Graafian follicles, and consists of connective tissue in several layers, the fibers of which are continuous with the looser fibers of the medullary portion. In these layers of cortical substance are embedded the ova enclosed in the Graafian follicle sacs."

THE OVUM.

"The human ovum was discovered in 1827 by von Baer, and it was he who first completely traced the connection between ova in the generative passages and ova in the Graafian follicles of the ovary.

"The conception of ova as the essential female element had, however, long been held, and Harvey's

PLATE I



UTERUS, FALLOPIAN TUBES, AND OVARIES.
POSTERIOR VIEW (SAPPEY).

The Female Organs of Reproduction: 1 1, ovaries; 2 2, Fallopian tubes; 3 3, fimbriated extremity of the left Fallopian tube, seen from its cavity; 4, opening of the left tube; 5, fimbriated extremity of the right tube, posterior view; 6 6, fimbriæ which attach the extremity of each tube to the ovary; 7 7, ligaments of the ovary at the hilum; 8 8 and 9 9, broad ligaments; 10, uterus; 11, cervix uteri; 12, os uteri; 13 and 14, vagina.

dictum of the seventeenth century that everything living is derived from an egg (*omne vivum ex ovo*) is well known.

"The human ovum as it comes from the ovary is a spherical, protoplasmic cell, averaging, with the zona radiata, approximately, $\frac{1}{127}$ of an inch in diameter.

"As in other cells, the cell body may be distinguished from the nucleus, the protoplasm of the former being called cytoplasm. In its finer structure the cytoplasm consists of an excessively delicate network of protoplasmic substance. Like other mammalian eggs, it probably contains, adjoining the nucleus, a minute, specially differentiated portion, consisting of a single or double centrosome surrounded by an attraction sphere.

"For some distance inward from the border the cytoplasm is pure and transparent, and this portion is often called the protoplasmic zone.

"Throughout the centre of the cell, however, it is obscured by the presence of an abundance of yolk substance, or deutoplasm, from which the corresponding part of the ovum is sometimes called the deutoplasmic zone.

"Deutoplasm is a non-living substance; it consists of granules of yolk embedded in the meshes of the cytoplasm network, and, like its analogue, the yolk

of the hen's egg, it serves as food for the future cells of the embryo.

"A comparison of the respective amounts of food in the human and the fowl's egg with the manner of embryonic development is suggestive.

"The chick develops outside the body of the hen, and therefore requires a large supply of nutriment, which it finds in the yolk and white of the egg.

"The child develops within the mother's body and receives its nourishment from the maternal blood; hence the supply of food within the egg is only enough to insure the beginning of growth, special bloodvessels being formed to facilitate its continuance.

"The nucleus, frequently called by its earlier name the germinal vesical, is spherical, and usually occupies a slightly eccentric position.

"Its protoplasm consists of a network composed of two kinds of material: the more delicate, slightly stained threads are the achromatic substance; the coarser, deeply staining portion the chromatic substance, or chromatin.

"The former is continuous with and probably of the same nature as the cytoplasm.

"The chromatin is peculiar to the nucleus, and at certain stages in the nuclear history is resolved into distinct granules or filaments, the chromosomes.

"The number of chromosomes in the human ovum before maturation is thought to be sixteen.

"There is every reason for believing that the chromatin is the bearer of whatever is inherited from the mother.

"The nucleus is limited by a nuclear membrane, and contains a strongly marked nucleolus, which has likewise retained its original name of germinal spot. There is probably no proper cell wall or vitelline membrane, such as is said to exist in many mammalian and other eggs.

"The ovum is surrounded by a thick, tough, transparent membrane of ovarian origin, and called zona radiata, or zona pellucida. It is pierced by a multitude of fine lines radiating from the surface of the zona to the ovum; these are thought to represent pores, to contain fine protoplasmic processes of the surrounding ovarian cells, and thus to serve as channels for the passage of nutriment to the egg.

"Between the zona radiata and the ovum are narrow spaces, where the perivitelline space exists. Attached to the outside of the zona radiata are usually patches of cells derived from the discus proligerus of the Graafian follicle of the ovary, which may form a complete covering and constitute the corona radiata. They disappear soon after the egg is discharged from the ovary."

THE GRAAFIAN FOLLICLE.

"The ova are enclosed in sacs called the Graafian follicles. The Graafian follicle presents several coats and is filled with an albuminous liquid.

"The entire number of follicles of all sizes in either ovary is about 35,000, or about 70,000 in both ovaries together. The sizes vary from the smallest primordial follicles, which are $\frac{1}{800}$ inch, to the largest, which are nearly half an inch in diameter.

"In the follicles which have attained any particular size there are the fully developed ova, one in each follicle, except in rare instances, when there are two ova in one follicle sac.

"The process which culminates in the discharge of the ovum from the ovary into the fimbriated extremity of the Fallopian tubes is as follows: The Graafian follicle gradually enlarges, becomes distended with liquid, which finally breaks through, and the follicle ruptures on the surface of the ovary, thus discharging the ovum. This is called ovulation."

CORPUS LUTEUM.

"After ovulation the empty follicle undergoes changes and becomes the corpus luteum. Usually the corpus luteum degenerates within a few days and

ultimately disappears. The ovarian scars left by the passing away of the corpus luteum also disappear in a short time."

THE FALLOPIAN TUBES.

"The primary function of the Fallopian tubes is to convery ova from the ovaries to the uterus; they also convey spermatozoa in the reverse direction. In some mammals the passage of the ovum down the Fallopian tube to the uterus occupies from three to five days; the time in woman is not definitely known, but is thought to be from four to eight days.

"The Fallopian tubes lead from the ovaries to the uterus. They are from three to four inches long, but their length is not always equal on the two sides. They lie between the folds of the broad ligament at its upper border opening into the uterus on either side of the cornua, where they present each a small orifice. From the cornua they take a somewhat undulatory course outward, gradually increasing in size, so that they are rather trumpet-shaped. Near the ovary they turn downward and backward.

"The extremity near the ovary is marked by fimbriæ. These fringe-like processes are free, all except one, and this one, which is longer than the others, is attached to the outer angle of the ovary, and presents

a little gutter or furrow extending from the ovary to the opening of the tube. This is two or three times larger than the uterus opening.

"Beneath the peritoneal coat, which is formed by layers of the broad ligament, is a layer of connective tissue containing a rich plexus of bloodvessels. This constitutes the proper fibrous coat of the Fallopian tubes. The mucous membrane is covered with ciliated epithelium, the movement of the cilia being from the ovary toward the uterus."

FERTILIZATION OF THE OVUM.

"Spermatozoa pass through the uterus into the Fallopian tubes, and even to the surface of the ovaries. It is known that spermatozoa reach the ovaries, as they have been seen in motion on their surface. The ordinary situation at which the ovum is fertilized is the dilated or external portion of the Fallopian tube. All authorities are agreed that fecundation does not take place in the cavity of the uterus.

"The main agency of the locomotion of the spermatozoa through the body of the uterus and the Fallopian tubes, and probably also from the vagina into the uterus, is the spontaneous movement of the spermatozoa themselves. By the lashing of their tails they wriggle their way over the moist surface, being

stimulated to lively activity probably by the opposing ciliary movements in the epithelium lining the passages.

"Kraft has shown in rabbits that when spermatozoa in feeble motion are placed upon the inner surface of the oviduct (Fallopian tubes) not only are they thrown into active contractions, but they move against the ciliary movements, that is, up the oviduct. The capacity of the male cell thus to respond by locomotion in the opposite direction to the stimulating influence of the ciliary cells over which they have to pass is an interesting adaptation. Probably this is the directive agency that enables the spermatozoa to follow the right path to the ovum. As has been seen, spermatozoa are probably capable of living within the genital passages for several days, when, if ovulation has not taken place, they perish. If, however, an ovum appears, they at once approach and surround it in great numbers, being apparently attracted to it in some mysterious manner. It may be, as has been strongly suggested, that also among animals the attraction may be a chemical one, the ovum containing or producing something for which the spermatozoa has an affinity. But experimental evidence upon this subject in animals is wanting.

"The spermatozoa appear to perforate the vitelline membrane of the ovum by the impulsive movement

of their filamentous extremity. And according to some observations, fertilization by a single spermatozoön takes place by a small orifice, or micropile, in the vitelline membrane, as first indicated by Barry.

"After the spermatozoön's arrival in the vitelline cavity of the ovum the spermatozoön disappears as a distinct organic element.

"The fertilized ovum enters the Fallopian tube, passes down the tube, and is covered by an albuminous layer. This layer forms around the fertilized and the non-fertilized ova alike in the tube, and it probably serves to protect the fertilized ovum. When the spermatozoids do not penetrate the vitelline membrane near the ovary it presents an obstacle to their passage into it, while the ovum is in the tube.

"We have seen that the essence of the whole process of fertilization is a fusion of the male and female nuclei, or, more exactly, a mingling of male and female chromosomes.

"As regards the mechanism of the passage of ova into the tubes, there are two theories in regard to the process: One, in which it is supposed that the fimbriated extremities of the Fallopian tubes at the time of the rupture of the Graafian follicle become adapted to the surface of the ovaries, and the other, that ova, being in themselves passive, are carried to

the opening of the tubes by ciliary currents. Neither of these theories, however, is susceptible of actual demonstration."

THE UTERUS.

"The uterus is a pear-shaped body, somewhat flattened anteriorly and posteriorly, presenting a fundus, a body, and a neck.

"At its lowest extremity is an opening into the vagina called the os externum. At the upper portion of the neck is a constriction which indicates the situation of the os internum, which is also called the cervix uteri.

"The uterus is usually about three inches long, two inches in breadth at its widest portion, and one inch in thickness. It is somewhat loosely held in place by the broad and round ligaments and by the folds of the peritoneum in front and behind. The delicate layers of peritoneum that form its exterior covering extend behind as far as the vagina, where it is reflected back on the rectum, and anteriorly a little below the upper extremity of the neck, where it is reflected upon the urinary bladder.

"At the uterus the peritoneal covering, a little below the entrance of the Fallopian tubes, becomes loosely attached and leaves a line for the penetration of the vessels and nerves.

"The interior of the uterus shows a triangular cavity, with two cornua corresponding to the openings of the Fallopian tubes, and have very thick walls.

"The inner muscular layer of the uterus is arranged in the form of broad rings which surround the Fallopian tubes, become large as they extend over the body of the uterus, and meet at the centre of the organ near the neck.

"The mucous membrane of the uterus is of a pale, reddish color, and that portion lining the body is smooth and so closely attached to the adjacent structures that it cannot be separated to any great extent by dissection.

"There is, indeed, no proper submucous areolar tissue, the membranes being applied directly to the uterine walls. It is covered by a single layer of cylindrical, epithelial cells, with delicate cilia, the movements of which are from without inward, toward the opening of the Fallopian tubes."

SOME OF NATURE'S MECHANICS FOR PREVENTING A LITTER OF OFFSPRING AT A SINGLE BIRTH AMONG HUMAN BEINGS.

The appearance among human beings of more than one child at a single birth, and sometimes of the two sexes, is evidence that both male and female ova

may and do mature and ovulate near enough at the same time to be fertilized at the same time and develop as boys and girls.

There are two facts connected with the fertilization of ova which act as preventives to a number of children at a single birth. One is that soon after the ovulation of ova they enter the Fallopian tubes and there receive an albuminous covering that spermatozoa cannot penetrate. This is supposed to protect ova that may have been fertilized before entering the oviduct, and also, if they have not been fertilized before entering it, to prevent fertilization in the Fallopian tubes. And, as the ovum takes on a preventive of fertilization, except at a given time and in a certain place, so there is also a prohibitive condition to fertilization of ova from both ovaries at the same time that appears in the progress of fertilizing spermatozoa when on their way into the uterus. That is, before entering the uterus the spermatozoa are embedded in the plasmic matrix substance, which draws them all together in one direction or another, and this direction is not only decided by the laws of gravity, but the plasmic fluid that contains them is helped to continue in the given direction by the fibrous rings it encounters in the interior of the uterus. And once it has reached the cornua of the uterus, the possibility of its flowing in another direction is greatly impeded,

if not prevented, by these fibrous rings and by the ciliary movements of the epithelium lining the uterine walls, the direction of which is from the neck of the uterus toward the Fallopian tubes.

As shown in Plate II, these fibrous rings occupy the right and left sides of the body of the uterus, each side having its own independent set of rings that do not overlap, but meet as a line in the middle of the body of the uterus. Also, it may be seen by this plate that both the right and left set of fibrous rings circle toward the opening of the right and left Fallopian tubes, respectively, as a centre.

Once the fertilization of an ovum takes place the cervix uteri of the normal uterus closes, and it would seem to prevent anything passing either into or out of the uterus.

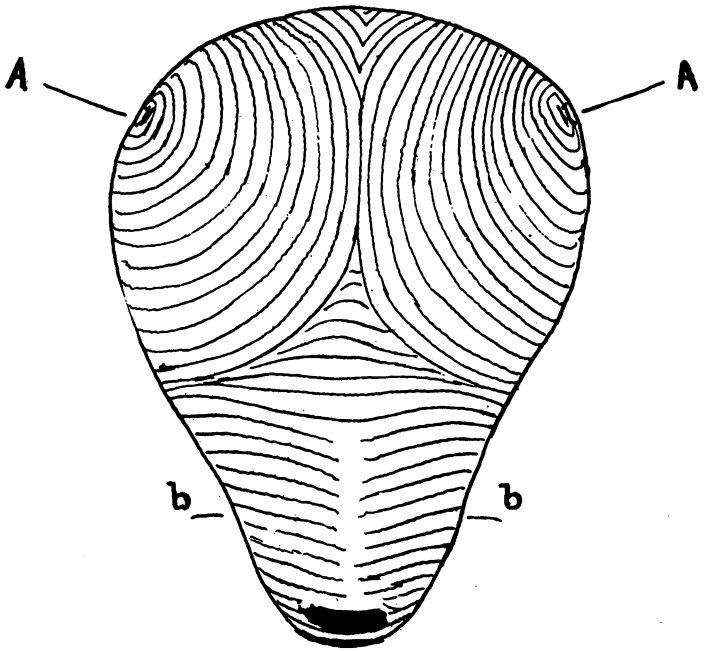
During pregnancy the ovaries cease to mature and ovulate ova, as all the vitality of the maternal organism is needed for the developing of the new life.

As a result of these mechanics, among others, no doubt the almost universal rule among human beings is that there is but one offspring at each birth.

CONCLUSIONS.

I maintain, from a practical experience of over thirty years, that in human beings the ova from the

PLATE II



INNER LAYERS OF MUSCULAR FIBERS OF THE UTERUS (LIÈGOIS).

The Inner Layer of the Muscular Fibers of the Uterus which are Accessory in the Determining of Sex: *a a*, rings around the openings of the Fallopian tubes; *b b*, circular fibers of the cervix.

right ovary fertilized develop as boys, and that ova of the left ovary fertilized develop as girls, in normal mothers.

I am also of the opinion that the right and left ova may be fertilized only by their complemental spermatozoa. In other words, that in human beings, and also in the higher animals, spermatozoa capable of fertilizing a given ovum, must be the complement of that ovum, and that, therefore, there are the two testes in the paternal animal as well as the two ova producing ovaries in the maternal creature.

Sixt's theory regarding the fertilization of ova, and that one side in the male caused the embryo from ova thus fertilized to become male, and from the other side to become female, was an evident and logical conclusion from his experiments, no doubt, only he failed to consider the other half of the whole story in the production of offspring.

In the light of the theory of sex determination as presented in this book, such experiments as Sixt made would be of practical value to all interested in this subject, either as parents of children or as breeders of animals.

It is my opinion that he was right as far as he went, but that he went but half way. For, according to the sex-determining theory as I have observed it, there can be no question of "inferiority" or "superiority"

of father or mother in the production of offspring or in the determination of sex. However, the directions given in this work for directing the fertilizing spermatozoa to the right or to the left side of the uterus, and consequently on to the right or left ovary, must be executed by the mother.

I hope this work will be accepted by physiologists and embryologists for whatever it may be worth to them after testing it by experiment; and that not only may they test the sex-determining theory with which I have had practical experience for some thirty years, but also that they, having access to embryological laboratories, may be inclined to assist in the possible verification of the other theories it contains, and which seem to be more or less relevant to the sex-determining law as I understand it.

For all women, especially mothers, who read it, I hope it may not only prove to be valuable and practical in what it contains, as well as whatever further knowledge it may help them to discover for themselves, but also that it may be a comfort to them in their hearts when they look upon their sons and daughters in the home according to their desire, and as a result of having the instructions that this little work contains, which is meant to put into their hands one of the longest sought-for keys to one of the most important secrets in Mother Nature's possession.

To the breeder of animals, I hope the suggested experiments in this work which I have made to them may prove to be valuable and practical assistance in some of the problems and difficulties they encounter, among whichever species their experience is cast.

PART II.

SEX-DETERMINING THEORIES AND BASIC PRINCIPLES INVOLVED.

CHAPTER V.

BASIC PRINCIPLES INVOLVED IN OTHER THEORIES.

At the beginning of the nineteenth century there were supposedly five hundred theories of sex determination. Besides this, a threatened increase was apparent, which would raise this number to much higher figures. And now, at the beginning of the twentieth century, some have gone so far as to say that the numbers of sex-determining theories have reached into the thousands.

For some the sex problem simply resolves itself into: "In the image of God created He him; male and female created He them. Be fruitful, and multiply, and replenish the earth. In the likeness of God made He him. Male and female created He them, and called their name Adam."

And, as was set forth by Geddes and Thomson in 1889, the academic metaphysicist looked for the "inherent properties of maleness and femaleness," and some scientists still refer to the "natural tendencies" as a cause of sex determination.

The analytical and synthetical scientist considers nutrition and environment of the parents especially important factors. It would appear that one reason why sex-determining theories regarding human offspring have varied but little since the remotest antiquity, and have proved inadequate, is because they have been deductions from facts derived from experimental investigations that have given specific results, but not connected with sex determination, though they have added generously to important knowledge regarding other phases of the living human being.

For instance, the profoundly valuable results obtained in the study and investigation of cellular life, beginning in 1838, with the history and facts established by those fathers and founders of the classical cell theory, Schlieden and Schwann. Yet these cell theories cannot locate in the cell the demarcation that would signify that from one egg a creature of four legs will be produced, from another one of two legs, and from another a creature of two legs and two wings. Nor the fact that a negress mother gave birth to two children at the same time—twins—one white and the other black. Yet these must be established facts in the germ cell of different species, and could not at all have occurred as "accidents in nature."

But to explain all the mysteries of our fearfully

and wonderfully made bodies, we shall have to wait perhaps until a spectroscope shall be invented that can trace all the story of creation in the history of the stars, and there read the facts of the "beginnings" of earth's vast, complex life—organic and inorganic. For, as Darwin concluded, "An organic being is a microcosm—a little universe—formed of a host of self-propagating organisms, inconceivably minute, and numerous as the stars of heaven." And, indeed, as imagined also by Democritus, Leucippus, Aristotle, Sir Oliver Lodge, and the rest, the units of organic and inorganic life combine in themselves a whole system of life, a centre positive body with negative bodies revolving around it, very much in the same way and seemingly in about the same proportionate distances as are manifest in our solar system, with its suns, planets, moons, and stars. And still on the threshold of this vast world, invisible to the naked eye, and which is avowedly capable of separation into simpler forms, a whole swarming life as multitudinous as the visible world around us, yet in this ultramicroscopic life we are eons of time away from the real "beginning" of all things from the Great One something—destined and bidden, after being sufficiently "fired up" and "cooled down," to produce the supreme creation—the human structure.

Pliny said, according to his English translator, Philoemon Holland, in 1601:

"Moreover, all learned men who are deeply studied in the secrets of nature, be of the opinion and do teach us, that in all trees and plants—nay, rather in all things that do proceed out of the earth, even in the very herbs—there are both sexes.

"Moreover, it is constantly affirmed of the palm trees that the female be naturally barren, and will not bear fruit without the company of the males among them to make them conceive. Yet grow they will, nevertheless, and come up themselves; yea, and become tall woods. And, verily, a man shall see many of the females stand about one male, bending and beaming in the head full kindly toward him, yielding their branches that way, as if they courted him for to win his love. But, contrariwise, he, a grim sir, and coy, carrieth his head aloft and beareth his bristled and rough arms aloft on high, and yet, what with his very looks, what with his breathing and exhalations upon them, or else from a certain dust that passeth from him, he doth the part of a husband, inasmuch that all females about him conceive and are fruitful with his only presence."

BASIC PRINCIPLE OF THIS SEX-DETERMINING LAW DIFFERS FROM ALL OTHER THEORIES ADVANCED UP TO NOW.

So far as I have been able to discover, no theory involving the principles of the sex-determining law have been set forth, such as I have discovered and presented in this work.

Professor T. H. Morgan, in his article on "Recent Theories in the Determining of Sex," in the *Popular Science Monthly* for December, 1903, mentions no theory involving the principles of the theory as I understand it; and Professor Edmund B. Wilson, of Columbia University, in his treatise, in 1909, on *Recent Researches on the Determination and Heredity of Sex*, mentioned no such theory.

No theory of all those reviewed by eminent men of science that I have been able to procure have either assumed or supposed a theory with the basic principle such as I maintain—that is, that the maternal creature's structure, provided with two ovaries, produces, matures, and ovulates from these two ovaries ova potentially male and female, the right ova potentially male and the left ova potentially female, in normal mothers.

The late Professor Cuénot, in his work on *The Determination of the Sex of Animals*, reviewed all the

leading theories of the world up to his time, classifying them, and finally concluded that as they had all failed of verification in more instances than they had succeeded, and as the basic principles of these theories varied but slightly from the remotest antiquity, therefore, they must have approached the subject from the wrong viewpoint.

Almost all of these theories involve the following principles, and, indeed, all with the exception of one, so far as I have been able to discover, involve some variation of the following idea:

The theory of cross-heredity involved in and necessary to the theory of nutrition, and also to the theory of dominance and segregation in sex determination, appears to be a dangerous and pernicious notion, as it requires the depletion of strength and vitality of one of the parents. There is probably but one way to meet this requirement, and at the same time the natural health and vitality of the parents be maintained, and that is by a great difference between the ages of the mother and father. But, so far as these cases have been investigated, the results have not proved anything satisfactorily in regard to sex determination. Indeed, these were often at variance with the supposed law rather than in accord with it.

As for nutrition, it cannot be denied that it has a

most vital and important part in the growth and development of the human parent body and of the offspring.

Probably no scientist could be found who would deny the value of nutrition as an important factor in the production of offspring, both boys and girls. Be it understood that this nutrition must be administered during the life of both parents, and with judicious regularity. As to the quality, let it be pure food and truly nutritious. If this is carefully followed, all that nutrition can do for the determination of sex in the human being will be done, and the result will "probably" be a fine child—either boy or girl—"as shown by the product."

As for the recent attempt to establish a theory based upon exclusive, alternating, periodic ovulation, which is supposed to be manifested only by menstruation, besides the want of physiological truth of this thesis, there does not seem to be practical value of any consequence arising from it. Its chief claim seems to be the possibility of predicting with a certain amount of accuracy, as claimed by its author, the sex of a coming child. As absolute knowledge on this point is manifest at the birth of the baby, the prediction of it, even though correct, could be of little if any value to the parents. But as a determining factor, its physiological unsoundness makes it value-

less, as the physiological fact concerning the maturation and ovulation of ova must contradict any conclusion arrived at from so fallacious a supposition.

HYPOTHESES BASED ON THE SEX-DETERMINING AW.

These few cases from my actual experience in observing the law of sex determination, as I understand it, so far as numbers are concerned, could be of small consequence in the great field of experimental evidence required by science in the ultimate establishing of a law or a principle, though they are part of the evidence that convinced me of the infallibility of this law during a period of thirty years. Their importance is their tests of the different phases of the law, and also that, once granted that they are examples of the sex-determining law among human beings, they necessitate hypotheses that extend farther than the simple fact of determining the sex of offspring.

"In the image of God created He him—male and female."

One of the first principles presented for observation and experimentation, it seems to me, is the fundamental part played by the male and female

elements or life in each individual organism. It seems almost necessary to the supposition of this theory of sex determination, as I understand it, that the male and female principles of living matter are primarily and fundamentally for the production of *life*—that is, to make alive—in whatever state, form, and species the given egg cell or sperm cell occurs. And other qualities and effects resulting from the necessary presence of the male and female elements of living matter are due mainly to their law, as set forth by Weissmann, of continuity. And that, therefore, the paternal influence does not reproduce itself, nor the maternal influence reproduce itself as determining factors in the sex of their offspring. But the male and female principles or elements of the egg cell and sperm cell have always a consortial union, each necessary to the other's existence, and separated they soon perish. The two, forever as two, make up the life both of the paternal and maternal germ cell. (See Dr. Edmund B. Wilson, of Columbia University, on the cell theories, quoted in this work; also, *The American Textbook of Physiology*, by Dr. William H. Howell.)

Parent organisms among human beings may produce sexless offspring. At the same time the life of those parents depends upon the presence of the male and female principles or elements of life combined

and in operation in their bodies according to the laws governing cellular life, and yet they may bring forth sexless offspring. And also this sexless offspring, of which there are striking and historic examples in human history, both among those with the secondary physical markings of men and those with the secondary physical markings of women, and which human beings have, as a rule, been more than ordinary as regards talents and genius, have and must have existed, according to the rules and laws of the cellular life, which make them living human beings, and yet they are sexless.

There are parents who, for some local reason, it may be said, are able to give birth to children of only one sex—either boys or girls—and yet, in their turn, these children, the offspring of such parents, give birth to children of the two sexes—both boys and girls. These cases offer opportunity for investigation regarding the part played by the male and female elements necessary to the production of the life of the individual cell which compose the whole organism.

Though the sex-determining law is a case of pure and simple mechanics in the matured organism, and has a value in this regard to the biologist, morphologist, embryologist, etc., in the simplicity and directness of it as a determining factor it evidently has to do

with the parental organisms' powers of reproduction by the ripened germ cells.

The following quotation from the *Catholic Churchmen in Science (Sketches of the Lives of Catholic Ecclesiastics Who Were Among the Great Founders in Science,* by James J. Walsh, M.D., Ph.D., LL.D., Professor of Medical History, Fordham University Medical School, and Professor of Physiological Psychology in St. Xavier's College, New York), from the chapter entitled "Abbot Mendel, a New Outlook in Heredity," has a bearing upon the foregoing statements, though they were originally written regarding reproduction and heredity among other than the human species. Dr. Walsh says:

"A very interesting phase of Mendel's discovery is concerned with the relative value of the egg cell and the pollen cell as regards their effect upon future generations. It is an old and much discussed problem as to which of these germinal particles is the more important in its influence upon the transmission of parental qualities. Mendel's observations would seem to decide definitely that in plants and by implication in animals, since the germinal process is biogenetically similar, the value of both germinal particles is exactly equal. In a note, Mendel says: 'In pisum (*i. e.*, in peas) it is beyond doubt that, for

the formation of the new embryo, a perfect union of the elements of both fertilizing cells must take place. How could we otherwise explain that among the offspring of hybrids both the original types reappear in equal numbers, and with all their peculiarities? If the influence of the egg cell upon the pollen cell were only external, if it fulfilled the role of nurse only, then the result of each artificial fertilization could be no other than that the developed hybrid should exactly resemble the pollen parent, or, at any rate, do so very closely. These experiments, so far, have nowise been confirmed. An evident proof of the complete union of the contents of both cells is afforded by the experience gained on all sides, that it is immaterial, as regards the form of the hybrid, which of the original species is the seed cell, or which the pollen parent.'

"This is the first actual demonstration of the equivalent value of both germinal particles as regards their influence on transmission inheritance in future generations. It is only by simplifying the problem, so that all disturbing factors could be eliminated, that Mendel succeeded in making his demonstration. Too many qualities have hitherto been considered, with consequent confusion as to the results obtained. It is of the genius of the man that he should have been able to succeed in seeing the problem in simple

terms while it is apparently so complex, and thus obtain results that are as far-reaching as the problem they solve is basic in its character."

CEREBROSPINAL AND SYMPATHETIC SYSTEMS AS THE CONSERVERS AND TRANSMITTERS OF MALE AND FEMALE STIMULI.

Is it not susceptible of demonstration whether or not different natured qualities are characteristic of right and left organs and ganglia which have connection with a corresponding right and left brain centre with the same characteristic qualities of those organs and ganglia? And also, if the reversing of the regular order of these characteristic qualities would be attended by the reversing of the usual location in the brain centre of those qualities.

If it is a fact that it is in the cerebrum—and in the perfect coördination of its complex, but never confused cerebrospinal and sympathetic systems—that the stimuli of the various functions of the body's organs are originated and sent forth to their infallible destiny for the life of the whole creature and also for the preservation of the species, then these two great systems, it would appear, receive, conserve, and transmit the male and female stimuli necessary for the body's psychophysical existence. And if,

through the media of these two systems, each particular organ controls the production of its own particular necessity, though the stimuli for its work are distilled from the whole organism and conducted to each organ by the arbitrary administering of these two systems; and if a given locality never errs in the quality or nature of its creation for the benefit of the whole completed organism—whether the organs are located in the body, according to the general rule of their location, as well as when the general order of location is reversed; therefore it appears that the cerebrospinal and sympathetic systems of cords, filaments, and fibers, with their ganglionic centres, become and are the efficient and economic conditions which meet the necessity for the generation, preservation, and transmission of the male and female elements or principles which make possible the living and perpetuation of the human organism.

The following quotations on the sympathetic system are taken from the works of Drs. Flint and Dalton:

"The nerves of the sympathetic system preponderate in the organs of nutrition, and in their influence on the functions of circulation, calorification, secretion, and growth.

"The cerebrospinal nerves are in greatest abundance and manifest their most striking properties in the organs of animal life.

"All the organs in the body contain nerve fibers from both sources, the difference consisting in the relative number of one kind or the other in particular parts.

"The ganglia on the spinal and cranial nerve roots are undoubtedly analogous, in their anatomical relations, to those of the sympathetic system; and this system may be considered as made up of nervous centres disseminated through the great cavities of the body, and connecting filaments which receive fibers from the cerebrospinal nerves and supply to these nerves fibers of their own." (Dalton.)

"In the cranium are the four cranial ganglia—the ophthalmic, the sphenopalatine, the otic, and the submaxillary.

"In the neck are the cervical ganglia—the superior, the middle, and the inferior.

"In the chest are the twelve thoracic ganglia, corresponding to the twelve ribs.

"The great semilunar ganglia, the largest of all in the body, and sometimes called the abdominal brain, are in the abdomen, by the side of the cœliac axis.

"The four lumbar ganglia are in the lumbar region in front of the spinal column.

"The pelvic ganglia, or the four or five sacral ganglia, are in front of the sacrum.

"Finally, the small ganglia in front of the coccyx

is sometimes called the last of the sympathetic cord, and consists of twenty-eight to thirty ganglia on either side and terminating below in a single ganglia.

"The four or five sacral ganglia and the ganglia impar are situated by the inner side of the sacral foramina and in front of the coccyx. These are connected with the ganglia above and with each other, and receive filaments from the sacral nerves, there being usually two branches of communication for each ganglion. The filaments of distribution go to all the pelvic viscera and bloodvessels." (Flint.)

"The muscular apparatus of the eye is under the control of two nervous influences derived, respectively, from the cerebrospinal and sympathetic ganglion.

"The iris receives all of its motor fibers from the ophthalmic ganglion. This is the first sympathetic ganglion in the head, on the orbit of the eye, on the outer aspect of the optic nerve.

"But those causing contraction of the pupil come through the ganglion from the oculomotor nerve; those causing dilatation are derived through the same channel, and from the central ganglion of the sympathetic system.

"The central part of the sympathetic system is a double chain of ganglia on the sides of the spinal column, united with each other by longitudinal filaments. Each ganglion is connected by motor

and sensitive fibers with the cerebrospinal system." (Dalton.)

"The cervical ganglia of the sympathetic lie on the spine at the base of the neck. The three cervical ganglia are situated opposite the third, fifth, and seventh cervical vertebræ. The middle ganglion is sometimes wanting, and the inferior ganglion is occasionally fused with the first thoracic ganglion. These ganglia are connected together by the so-called sympathetic cord. They have a number of filaments of communication above with the cranial ganglia and with the cervical nerves of the cerebrospinal system.

"From the cervical portion of the sympathetic three cardiac nerves arise and pass to the heart, entering into the formation of the cardiac plexus. The superior cardiac nerve arises from the superior ganglion; the middle nerve, the largest of the three, arises from the middle ganglion, or from the sympathetic cord when this ganglion is wanting; and the inferior nerve arises from the inferior cervical ganglion, or from the first thoracic ganglion.

"These nerves present frequent communication with various of the adjacent cerebrospinal nerves, penetrate the thorax, and form the deep and superficial cardiac plexus.

"In these plexuses are found ganglioform enlargements, and on the surface and in the substance

of the heart are collections of nerve cells connected with the fibers.

"The thoracic ganglia are situated in the chest, beneath the pleura, and rest on the heads of the ribs. They usually are twelve in number, and occasionally two are fused into one. They are connected together by the sympathetic cord. They each communicate by two filaments with the cerebrospinal nerves. One of these is white, like the spinal nerves, and probably passes to the sympathetic; the other is of a grayish color, and is thought to contain the true sympathetic filaments.

"From the upper sixth ganglia, filaments pass to the aorta and its branches. The branches that the posterior pulmonary plexus arise from are the third and fourth ganglia.

"The great splanchnic nerve arises mainly from the seventh, eighth, and ninth ganglia, receiving a few filaments from the upper sixth ganglion.

"This nerve is a large, white, rounded cord which penetrates the diaphragm, and passes to the semilunar ganglia, sending a few filaments to the renal plexus and the suprarenal capsules." (Flint.)

"In the abdomen the sympathetic system arises mainly from an aggregation of ganglionic enlargements situated on the cœliac artery, known as the semilunar or cœliac ganglia. From this centre a

multitude of diverging and inosculating branches are sent out, which, from their common origin and radiating course, are termed the solar plexus. Its secondary plexuses accompanying the branches of the abdominal aorta are distributed to the stomach, intestines, spleen, pancreas, liver, kidneys, suprarenal capsules, and internal organs of generation.

"In the pelvis there are four or five pairs of ganglia, situated on the anterior aspect of the sacrum, and at its lower extremity the ganglion impar, which is regarded as a fusion of two symmetrical ganglia.

"In all of these parts the main characteristic of the sympathetic nerves is their arrangement in the form of plexuses, which surround the arterial branches and follow their peripheral distribution in the vascular organs." (Dalton.)

"The lesser splanchnic nerve arises from the tenth and eleventh thoracic ganglia, passes into the abdomen, and joins the cœliac plexus, which is the largest sympathetic ganglion in the body.

"The renal splanchnic nerve arises from the last thoracic ganglion and passes to the renal plexuses, These three splanchnic nerves—the great, the lesser, and the renal—present frequent anastomoses with each other." (Flint.)

"The sympathetic ganglia and nerves are endowed both with sensibility and the power of exciting

"So far as has been shown by anatomical investigation, there are no fibers derived exclusively from the sympathetic that are distributed to striated muscles, except those which pass to the muscular tissues of the heart." (Flint.)

CHAPTER VI.

DR. ERASMUS DARWIN ON HUMAN GENERATION AND SEX DETERMINATION IN THE YEAR 1784.

I should think there could be no earnest investigation or sincere thought made in any department of science, and that effort be considered as thorough, without knowledge of what Darwin thought upon the same; that is, Dr. Erasmus Darwin, grandfather of the modern Charles Darwin. For surely in Dr. Erasmus Darwin may be found the suggested outlines at least of all "Darwin's demesnes." For he was a truly great originator, thinker, citizen, and man. Besides actual data, as is well known to all, he projected abstracts and formulas on scientific subjects alone sufficient to keep his generations of offspring valuably occupied for much time to come.

Although he was considered the greatest physician of his time, which was the eighteenth century, especially the last half, yet his ideas, as expressed by himself on the subject matter of this little book, and the physiological subjects connected with it, seem almost as matters of curiosity, merely, today.

In the light of the nineteenth and twentieth centuries, cellular theories and history, and especially in connection with the experiments and theories of Abbot Mendel, as set forth in his *Principles of Heredity in the Laws of Dominance and Segregation*, Erasmus Darwin's *Zoönomia*, or the *Laws of Organic Life*, appears in many respects as a most interesting curiosity, especially in his chapter devoted to the general subject of generation, and especially in the part of it devoted to the study of the human being. Although, on the other hand, much of it might have been written in the light of modern scientific discoveries, but always Dr. Erasmus Darwin's thought projects plenty of pure science, plenty of true philosophy, and plenty of poetical imagination of the highest order.

The following quotations from the above-mentioned book are selected out of the great mass on the general subject of generation, as they bear principally on reproduction of offspring, and set forth his principle of sex determination.

Of *Zoönomia*, Dr. Erasmus Darwin, its author, said himself: "I am studying my *Zoönomia*, which I think I shall publish, in hopes of selling it, as I am now too old and hardened to fear a little abuse. Every John Hunter must expect a Jessy Foot to pursue him, as the fly bites a horse."

This work was translated into German, French, and Italian. The *Zoönomia* was published May 1, 1794, from which the following excerpts are made:

"The ingenious Dr. Hartley, in his work on man, and some other philosophers, have been of the opinion that our immortal part acquires during this life certain habits of action or of sentiment which become forever indissoluble, continuing after death in a future state of existence; and add, if these habits are of the malevolent kind, they must render the possessor miserable, even in Heaven. I would apply this ingenious idea to the generation or production of the embryon, or new animal, which partakes so much of the form and propensities of the parent.

"Owing to the imperfection of language, the offspring is termed a new animal, but is in truth a branch or elongation of the parent; since a part of the embryon animal is or was a part of the parent, therefore in strict language it cannot be said to be entirely new at the time of its production; and, therefore, it may retain some of the habits of the parent system.

"At the earliest period of its existence the embryon, as secreted from the blood of the male, would seem to consist of a living filament, with certain capabilities of irritation, sensation, volition, and association, and also with some acquired habits or

propensities peculiar to the parent. The former of these are in common with other animals; the latter seem to distinguish or produce the kind of animal, whether man or quadrupeds, with the similarity of feature or form to the parent. It is difficult to be conceived that a living entity can be separated or produced from the blood by the action of the gland; and which shall afterward become an animal similar to that in whose vessels it is formed, even though we should suppose, with some modern theorists, that the blood is alive; yet every other hypothesis concerning generation rests on principles still more difficult to our comprehension.

"At the time of procreation this speck of entity is received into an appropriate nidus, in which it must acquire two circumstances necessary to its life and growth; one of these is food, or sustenance, which is to be received by the absorbent mouths of its vessels; and the other is that part of atmospherical air or water which by the new chemistry is called oxygene, and which affects the blood, by passing through the coats of the vessels which contain it. The fluid surrounding the embryon in its new habitation, which is called liquor amnii, supplies it with nourishment; and as some air cannot but be introduced into the uterus along with the new embryon, it would seem that this same fluid would, for a short

time, suppose for a few hours, supply likewise a sufficient quantity of the oxygene for its immediate existence.

"The idea of the reproduction of animals from a single living filament of their fathers appears to have been shadowed or allegorized in the curious account in sacred writ of the formation of Eve from a rib of Adam.

"From all these analogies I conclude that the embryon is produced solely by the male, and that the female supplies it with a proper nidus, with sustenance, and with oxygenation; and that the idea of the semen of the male constituting only a stimulus to the egg of the female, exciting it into life, has no support from experiment or analogy.

"Others have supposed that all the parts of the embryon are formed in the male previous to its being deposited in the egg, or uterus, and that it is there only to have its parts evolved or distended, as mentioned above; but this is only to get rid of one difficulty by proposing another equally incomprehensible; they found it difficult to conceive how the embryon could be formed in the uterus, or egg, and therefore wished it to be formed before it came thither."

The following was Erasmus Darwin's theory of sex determination: "The imagination of the male forms the sex." There probably could be no more striking

and brilliant exponent of Mendel's laws of heredity than is set forth in the Darwin generations, beginning even with the family when it appears in the seventeenth century, on up to Dr. Erasmus Darwin, during the eighteenth century, and overlapping into the nineteenth century, as exemplified by his grandson, Charles Darwin, and extending on up to our present day eminent scientists of that same name and fame.

Dr. Erasmus Darwin was not only a scientist but a genius of exceptional mechanical skill, and a poet of no mean quality, when Horace Walpole, in May 14, 1792, speaks of him in the following words: "The 'Triumph of Flora,' beginning at the fifty-ninth line, is most beautiful and enchantingly imagined; and the twelve verses that by miracle describe and comprehend the creation of the universe out of chaos are the most sublime passages in any author, or in any of the few languages with which I am acquainted. There are a thousand other verses most charming—or, indeed, all are so—crowded with most poetic imagery, gorgeous epithets, and style; and yet these four cantos do not please me equally with the 'Loves of the Plants.'"

The following lines are the ones Horace Walpole quotes from Erasmus Darwin's "The Botanic Garden:"

"'Let there be light!' proclaimed the Almighty Lord.
Astonished Chaos heard the potent word;
Through all his realms the kindling ether runs,
And the mass starts into a million suns.
Earths round each sun with quick explosions burst,
And second planets issue from the first;
Bend, as they journey with projectile force,
In bright ellipses their reluctant course.
Orbs wheel in orbs, round centres centres roll,
And form, self-balanced, one revolving whole.
Onward they move amid their bright abode—
Space without bound, the bosom to their God."

As believer and Christian, the following ode and saying of his give evidence:

"Dull atheist, could a giddy dance
Of atoms lawless hurl'd,
Construct so wonderful, so wise,
So harmonized a world?"

The following evinces his quality as patriot and politician. In April 13, 1789, he writes:

"I have just heard that there are muzzles or gags made at Birmingham for the slaves in our islands. If this be true, and such an instrument could be exhibited by a speaker in the House of Commons,

it might have a great effect. Could not one of their long whips or wire tails be also procured and exhibited? But an instrument of torture of our own manufacture would have a greater effect, I daresay."

The following quotations on slavery appeared in Canto Three of "The Loves of the Plants," in 1790:

"Throned in the vaulted heart, his dread resort,
Inexorable conscience holds his court;
With still small voice the plots of guilt alarms—
Bares his mask'd brow, his lifted hand disarms;
But, wrapp'd in might, with terrors all his own,
He speaks in thunder, when the deed is done.
Hear him, ye Senates! hear his truth sublime—
He, who allows oppression, shares the crime."

AN OBSERVATION MADE BY HIPPOCRATES.

It is a curious and interesting fact that at a time as modern as the last half of the eighteenth century the eminent scientist and physician, Dr. Erasmus Darwin, speaks of the uterus as the egg (meaning the human ovum). And it is equally curious and interesting that the human ovum, or egg, was not discovered until 1827, by von Baer; and that, therefore, up to that date (1827) there could not have been a theory regarding the determination of sex of

human beings which involved the knowledge of the location in the ovaries of the human ovum or human egg. In view of this history, it is interesting to recall the fact that the science of human anatomy was first and especially developed at the great medical University of Bologna, and that

"Mondino had, very early in the fourteenth century, re-created the modern science of anatomy, as we know it. He was the first to realize the importance and urge the necessity for the dissection of human bodies, if any real lasting progress in human anatomy was to be made. Medical teaching before this time had been largely by lectures and disputations upon the work of Aristotle, Hippocrates, and Galen, but actual observations on human tissues and organs, now replaced the older methods.

"From Mondino to Morgagni there is a continuous series of great men. About midway between these two men came the great Vesalius, who taught at Bologna, as well as Padua and Pisa, and whose work on anatomy was to be a treasure for anatomists of all countries for many generations. It was while teaching at Bologna that Vesalius made the famous series of dissections which formed the subjects of the illustrations for his great work on anatomy. Titian, the celebrated Venetian artist, who had come down from Venice in order to study anatomy, for

artistic purposes, at the famous school of anatomy, and under the supervision of its great teachers, is said to have executed the plates for the book." (*Makers of Modern Medicine*, by James J. Walsh, M.D., Ph.D., LL.D., Acting Dean and Professor of the History of Medicine and of Nervous Diseases, Fordham University Medical Schools; Adjunct Professor of Medicine at the New York Polytechnic School for Graduates in Medicine, and Professor of Physiological Psychology at St. Xavier's College, New York.)

It is in the light of this history that it is of particular interest to note that in the far away time between 400 B.C. and 370 B.C. this same Hippocrates mentioned in the above quotation is reputed to have made the following observation upon fetuses, and in connection with his observation it is of particular interest to keep in mind that the discovery of the human ovum was not made until 1827 of the Christian era, which discovery was made possible, it would appear, after the great Bologna University should have set up the fathers and founders of anatomical investigation of the human body especially by dissection, and that these great men should have all passed away, leaving their important work and valuable discoveries, which opened a sure way for this great discovery of the human ovum, or egg, and for

the work of those great founders of the cell theory—Schwann and Schleiden—both of these great events belonging to the nineteenth century of the Christian era.

It was between 400 B.C. and 375 B.C. that this great medical scientist, Hippocrates, observed:

"It is a fact observed by me, and every careful observer will find it to be true, that in the last month of pregnancy the fetus always lies habitually either to the right or left side. In case it lies to the right side, it can be proved by investigation that the fetus lies with its back to the right, and in this case a male child is born. On the other hand, if the fetus lies with its back to the left, a female child is born."

It is evident to me from this observation of Hippocrates that if the great philosopher had lived after the discovery of the human ova, or egg located in right and left ovaries, that is, after 1827, he would have surely substantiated my discovery of the law of the determination of sex of human offspring; but, naturally, he knew nothing of the fact of the existence of human ova, or egg, though much experimentation was made and much theorizing was done during his time on the question of the egg of the feathered world, especially the eggs of pigeons. But what could they really learn of human mothers from the conditions governing the bird mothers?

CHAPTER VII.

EXCERPTS FROM THE HISTORY OF THE GENERAL SUBJECT OF SEX, BY WILLIAM H. HOWELL, PH.D., M.D.

"In the highly specialized sexual reproduction of higher animals, including man, the individuals of the species are of two kinds of sexes, the male and the female, with profound morphological and physiological differences between them. In each the protoplasm of the body consists of two kinds of cells—somatic cells and germ cells—the former subserving the nutritive, muscular, and nervous functions of daily life, the latter subserving reproduction. The germ cells of the male, called spermatozoa, are relatively small and active; those of the female, called ova, are relatively large and passive. The reproductive process consists of the fusion of a male and female germ cell, the essential part being a fusion of the nuclei; and this is followed by continued sexual cell division and growth into a new individual." From the *American Text-book of Physiology*, second edition, edited by William H. Howell, Ph.D., M.D.

ORIGIN OF SEX AND THEORY OF REPRODUCTION IN GENERAL.

"Among living beings two methods of reproduction are recognized—the asexual and the sexual. Both are widespread among animals and plants, but the asexual method is the more primitive of the two, and is relatively more frequent in low organisms. The sexual method, the only one present in the production of new individuals among the higher animals, has evidently been acquired gradually, and has probably been developed from the asexual method."

ASEXUAL REPRODUCTION.

"Asexual reproduction, or agamogenesis, is the chief method of reproduction among unicellular plants and animals.

"Among various species it takes various forms, known as fission or division, gemmation or budding, endogenous cell formation or multiple fission; but all the varieties are modifications of the simplest form—fission or division. In fission, found only in unicellular organisms and typified in amebæ, the protoplasm of the single cell, together with the nucleus, becomes divided into two approximately equal portions, which separate from one another.

"In this process no material is lost, and two inde-

pendent, nucleated, organisms result, each approximately half the size of the original. The parent body has become bodily transformed into the two offspring, which have only to increase in size by the usual processes of assimilation in order themselves to become parents."

SEXUAL REPRODUCTION.

"The explanation of sexual reproduction is much more difficult, for here, in addition to the budding of the germ cells of the parent bodies, which probably has the same fundamental cause as fission in unicellular forms, we must account for the differentiation into sexes, the existence of special sexual cells, and the fusion of the male and female germinal substance; in short, we must account for the conception of sexuality itself and all that it implies.

"Regarding the origin of sexuality itself, as to the question whether sexuality is an original and fundamental attribute of protoplasm, or has been acquired, we may say at once that at present we know really nothing."

PRIMARY AND SECONDARY CHARACTERS.

"In the human species, as in all the higher sexual animals, the characters of sex, anatomical, physiological, and psychological, are divisible into two

classes, called primary and secondary. Primary sexual characters are those that pertain to the sexual organs themselves and to their functions. They are naturally the most pronounced of all the sexual attributes.

"Secondary sexual characters comprise those attributes that are not directly connected with the sexual organs, but that, nevertheless, constitute differences between the sexes. Such are the greater size and strength of man's body as compared with woman's; the superior grace and delicacy of woman's movements; the deeper, rougher voice of man, and the higher, softer voice of woman. In reality, all secondary sexual characters are accessory to the primary ones. The primary sexual characters of the male centre in the production of spermatozoa and the process of impregnation; those in the female in the production of ova and the care of the developing embryo." The above quotations are from *The American Text-book of Physiology*, second edition, edited by William H. Howell, Ph.D., M.D.

With regard to the origin of sex, John Adam Ryder says:

"A careful survey of the living world leads to the conclusion that sexuality has been, in all probability, one of the many results of the operation of the forces of evolution. A still further examination of the data of sexuality leads to the conclusion that the method

of it which may be observed in the vegetable and animal world has proceeded along two parallel but distinct lines of progress. Both have ended in the achievement of the same result, namely, viviparity, or the production of offspring in the advanced state of development, before the latter is set free from the parent to begin an independent existence for itself. An acorn is as truly a product of viviparous development as an infant human being. Without questioning the high value of the results of such experimental investigations, the question of the origin of sex is probably nearly, or quite, beyond the pale of experimental inquiry, in virtue of the fact that even the lowest organisms in which sexuality is manifested are already so persistently adapted to a certain habit of life, and are consequently so fixed in organization, that experimental investigation, looking to a modification of their reproductive processes through artificial interference, is quite impossible within the limits of a single lifetime devoted to experimental research."

T. W. Heineman, in his studies of the history of the origin of sex, traces the evolving of the perfected power of reproduction through varying grades of living organisms as follows:

"The simplest kind of reproduction is hard to distinguish from mere overgrowth. The next higher

step in reproduction is by gemmation. In the next higher form of reproduction there appears a tendency of the reproductive substance to fall apart into two different materials—that is, the male and female reproductive matter. These two different substances, representing different functions and potencies, occur at this stage, however, in the same individual. In a step still higher, the male reproductive material has acquired separate existence. It lives apart from the body of the individual containing the bulk of the female substance. But in this primary form of the sexes, the male has hardly any other functions or organs besides those appertaining exclusively to reproduction.

"It has been reported by microscopists that in this the lowest form of sexual life the male is sometimes absorbed into the female organism by serving as food.

"In the highest type of sexual reproduction both the male substance and the female are each contained in a separate organ, and each of these is specialized to its own part of the reproductive process exclusively. Each of these organs is, then, a part of a well-developed individual of the race type.

"The individuals of such races are distinguished as being of male or female sex, and neither sex at this stage can reproduce without the other.

"The process by which like concentrates with like and dissociates from unlike has practically been continuously at work upon the reproductive substance of the universe as a unit ever since life first began on earth. Therefore, the reproductive substance contained in any form of life today represents for that form the total result of this process of concentration and dissociation, since life first began on the earth, and in the highest form of sexual development this process has nearly reached perfection."

CHAPTER VIII.

EXCERPTS FROM CELLULAR LIFE HISTORY AS SET FORTH BY LEADING SCIENTISTS OF THE NINETEENTH AND TWENTIETH CENTURIES.

Dr. Edmund B. Wilson, of the Columbia University, has said:

"Nothing in biological history or research in the last twenty-five years surpasses or even equals the following three achievements: (1) The theory of organic evolution; (2) the discovery of the fundamental relations between animals and plants; and (3) the establishment of the cell theory and the recognition of protoplasm as the physical basis of life.

"It is certain that new results of the highest interest relating to the chemical conditions in living matter may be looked for along the lines of research thus opened.

"One of the most specific problems in this direction is the long-standing one of sex determination."

Dr. Wilson's latest leanings regarding sex determination are toward the Mendelian theory, which is a law in heredity. His experiments are devoted principally to insects.

According to Professor T. H. Morgan, statistics do not bear out the fact of the working of the Mendelian theory in heredity as a law for the determination of sex.

Scientists are generally agreed that an animal cell is composed of two sharply distinct organs—(1) a cell body (cytosome), and (2) a nucleus (caryosome). That the properties of a nucleated cell are, broadly speaking, (1) those tending to the preservation of the individual cell, and (2) those tending to the maintenance of the species.

They are generally agreed, also, "That the predetermined factors in the cell are constitution and organization, and that organization is not structure.

"Constitution is the chemical and physical individuality of the cell substance.

"Organization expresses the fact that the chemical and physical properties of the substance are not equally distributed through the entire mass, but are bound, separately, to lesser morphological units.

"Structure is the specific arrangement of the elements of like character into groups, instigated by external stimulus. In other words, structure is the expression of the most direct path along which specific response must travel in order to meet a specific stimuli."

According to Professor Watase, the generally accepted belief regarding a nucleated cell is that:

"A nucleus in its resting stage has a definite membrane around it, called the nuclear membrane, or caryotheca.

"The cell body (cytosome) is a network of cytoplasm. This network contains within its own substance small bodies of varying sizes, which are known as the microsomes; or, more strictly, the cytomicrosomes. Surrounding the cytosomes there is a membrane, known as the cell membrane or cytotheca. It may exist as a thickened border of the cytosome or as a distinct membrane separate from the cytosome.

"The meshes of the cytoplasm are filled with a fluid substance commonly called the cytoplasmic fluid, or, to use Haeckel's term, the cytolymph.

"The cytolymph is the only living portion of the cell body, and hence properly belongs to the category of protoplasm, in the most striking sense of the word.

"The cytoplasm contains the inert, passive, non-living portion of the cell body. Besides the cytolymph there usually exist a number of non-living bodies in the cell body, as yolk granules, oil drops, debris of food, zymogen granules, etc., according to the nature of the different cells. These non-living substances altogether belong to the group known as metaplasm, or paraplasm, in contradistinction to the

substance which is the real living element in the cell, the protoplasm.

"The contents of the nucleus (caryosome) may be arranged into two similar groups of living and non-living elements.

"The chromosomes of the nucleus are distinctly protoplasmic in character, and so is the fine network achromatic thread-like substance which is often found traversing the nuclear cavity. In several cases, if not in all, these filaments are the actual continuation of the cytoplasmic network existing around the membrane.

"The fluid which bathes these semisolid living constituents of the nucleus is known as nuclear fluid, or caryolymph.

"In the caryolymph there exists a body known as the nucleolus. In certain cases the filaments of the chromosomes have been found passing through the substance of the nucleolus, or directly ending in it. Sometimes only one nucleolus exists in each nucleus, while in other cases over one hundred nucleoli may be found in each nucleus. The number of nucleoli is quite variable in different cells, but fairly constant in a given species of cell.

"The microchemical reaction of the nucleolus is entirely different from that of the chromosome. It appears probable that three or four different bodies

are included under the name of nucleolus. Indeed, one sees no reason why the inside of the nucleus membrane may not be used as a depository for some solid products of cell metabolism, under certain circumstances, just as the spaces in the cell body are used for such a purpose. And thus some of the bodies included under the generic name of nucleolus may belong to the group of metaplasm.

"To recapitulate:

"The chromosome and the cytoplasm are the two active, living constituents of the cell.

"The rest of the bulk consists of non-living substances which have yet to be converted into vital elements, or are the products of metabolism, which have now lost the distinctive characteristics of a living substance. The behavior of the cytoplasmic thread, or network, suggests that it is formed of a group of small, living particles, each with the power to assimilate, to grow, and to multiply by division.

"The chromosome, in the same way, is itself a colony of minute organisms of another kind, each endowed with similar attributes of vitality.

"The media in which they live—the cytolymph and caryolymph—are the media in which they breathe, from which they derive their nourishment, or within which they deposit their products of metabolism.

"The reason why the cell as a whole assimilates,

grows, and divides is ultimately due to the fact that the minute particles which compose the cytoplasm and the chromosome are endowed with these functions.

"Two important activities in the developmental phases of protoplasmic life are cell division (karyokinesis) and cell fusion (fecundation).

"The organs of an individual cell are studied from three viewpoints—physiologically, morphologically, and phylogenetically: (1) How far are nucleus and cytoplasm adapted by their form and structure to perform their physiological work in a given cell? (2) Morphologically, in what manner do they originate in a given cell? This immediately resolves itself into the problem of cell division and cell fusion. (3) What are the probable steps in the ancestral history by which these structures came into existence? This belongs to the broad question of cytogeny, understood in its phylogenetic sense.

"According to the morphological view, however complicated one of the higher animals or plants may be, it began its separate existence under the form of a nucleated cell. This, by division, became an aggregate of nucleated cells; the parts of this aggregate, following different laws of growth and multiplication, give rise to the rudiments of the organs; and the parts of these rudiments, by the needful modes of multipli-

cation and metamorphosis, convert the rudiments into the perfect structure.

"Writers agree that the identity of the nucleus and the cytoplasm is never once lost during the whole series of remarkable changes. There is a continuity of nuclear matter from one phase to another, just as there is a continuity of cytoplasm through the successive periods in the history of the cell. The nucleus always originates from a preceding nucleus, and the cytoplasm from a preceding cytoplasm. There is no evidence proving that the nucleus is formed by the process of differentiation from the cytoplasm, nor that the cytoplasm is formed by the differentiation of the nuclear substance. Thus we are led to regard the two substances as independent structures, although each is necessary to the physiological existence of the other."

All writers unanimously agree "that the cell itself was formed out of still smaller organisms which already existed, somewhat like the physiological units which constitute the cytoplasm and the nucleus of a cell, but each with the power of assimilating, growing, and multiplying by division—ultramicroscopic organisms. Separating the cytoplasm from the nucleus in a given cell, and then separating them smaller and smaller, we should come to the physiological unit."

All writers, however, do not agree upon the name of this physiological unit. It has been called by many different names, that are almost but not always synonymous. They were called, in 1887, the bioblasts of Altmann; in 1888, the somacules of Foster; in 1889, the panganes of Hugo de Vries; in 1893, the plasomes of Wiesner; in 1893, the biophores of Weissman, or "his bearers of vitality," because they are the smallest units which exhibit the primary vital forces; in 1893, the idioblasts of Hertwig; and then there are the gemules of Darwin; the miscellæ of Nageli; the plastidules of Elsberg-Haekel; the microzymes of Bechamp-Estor; and the physiological units of Spencer.

"The vital properties of a cell do not reside in the nucleus alone, nor in the cytoplasm which surrounds it, but in the two together. The cell may be destitute of a wall, or it may be enclosed within its own cell membrane, or a cell may exist side by side with other cells without any visible boundary between them.

"The limitations of the cells are the expression of the organic cohesion of a system of biosomes associated to form an organic unit. We may therefore compare the cells in a rude way to the solar system, in which also a number of different elements are held together by the cohesion of the universe (gravitation)

and form one unit. There is no wall around it, yet there is a distinct limitation.

"The chromosomes cannot grow beyond a certain bulk, nor is the cytoplasm capable of unlimited growth, without each meeting restraining influences from the other. The division of the cell, when such exists, is the result incidental to the increase in the number of two kinds of cell forming organisms existing in each nucleated cell."

Since the founders of the classical cellular theory by Schlieden and Schwann, in 1838 and 1839, scientists generally agree that to explain the nature of a nucleated cell four well-ascertained facts with regard to nucleus and cytoplasm must be explained and held under common view, and must recognize the profound physiological interdependence between the nucleus and the cytoplasm, and also recognize their morphological independence. These four facts are:

"1. The two elements in each cell—chromosome and the cytoplasm—have the capacity for assimilation growth and multiplication by division.

"2. Each is essential to the physiological existence of the other.

"3. The chromosome always originates from preceding chromosome, and cytoplasm from preceding cytoplasm.

"4. Each has a definite chemical reaction, dif-

ferent from the other, and is composed of different chemical substance."

To explain a nucleated cell and its cellular life, inviolately, would mean to give a definition of life itself. Therefore, before considering the leading scientists' cellular theories, it may be well to remember what Dr. Graf has said on the possibility of an infallible cellular theory. He says:

"We cannot give a definition of life itself, because we come to the conception of life only by a deduction. Life is the unknown cause of a series of effects which we call life phenomena; for example, growth, irritability, division, self-determination, etc. We find that all these phenomena, or functions of life, may, under favorable conditions, be performed by one single cell, as is the case with the protozoöns and in the wandering cells of the metazoön body."

Professor Watase applies De Bary's doctrine of symbiosis to the association of the two different kinds of cell-forming organisms in each cell as the best possible explanation of cellular life. He finds that Darwin's idea of a cell expressed in his theory of pangenesis, and in its special aspect which considers mutualistic symbiosis as the basis for cellular organization, adds a more concrete meaning to his well-known passage.

"An organic being is a microcosm—a little universe

—formed of a host of self-propagating organisms, inconceivably minute, and numerous as the stars of heaven."

Professor Watase says that in a restricted sense symbiosis means the normal fellowship, or the consortial union of two or more organisms of dissimilar origin, each of which acts as the physiological complement to the other in the struggle for existence. He summarizes the general consequence of the symbiotic existence to its participants as follows:

"1. Inasmuch as one organic being comes in connection with another in order to be nourished, and to nourish the other in return, they obtain a freedom in choice of dwelling place which is not enjoyed by them otherwise.

"2. Symbiosis of two dissimilar organisms induces certain modifications in each symbiont, by the suppression of certain characters originally present in each, or by the acquisition of others which were formerly absent.

"3. When the adaptation of one symbiont to the other becomes perfect, the whole community behaves like a new organism, subject to new laws of growth and development, and is no longer subject to those relating to each symbiont separately.

"4. A power of adaptation to the external world, which each symbiont did not possess individually in

the struggle for existence, may be acquired indirectly or by the combined efforts of the two.

"5. In proportion as the symbiotic adaptation of two or more organisms becomes more and more perfect, each symbiont loses the power of living independently which it originally possessed."

Professor Watase claims that the symbiotic significance to the cellular life of the two different kinds of cell-forming organisms in each cell explains:

"1. The constant difference in anatomical, optical, and microscopic characteristics between chromosome and the cytoplasm.

"2. The maintenance of their specific identity through all phases of their developmental changes, as in karyokinesis and fecundation.

"3. The participation of both nucleus and cytoplasm in the manifestation of non-developmental phenomena of cell life such as secretion and excretion.

"4. The interchange of metabolic products between nucleus and cytoplasm as the necessary outcome of a symbiotic mode of existence.

"5. The reason why the cytoplasm, separated from the nucleus, or the nucleus isolated from the cytoplasm, invariably perish

"6. Why the nucleus and the cytoplasm are the physiological organs of a cell, and yet they are not

the organs from a morphological or developmental standpoint."

Dr. Arnold Graf, in his lecture on the "Individuality of a Cell," in 1895, reviews three different cellular theories. He says:

"The classical theory of Schlieden and Schwann, the fathers of cellular theories, is based upon the facts of the formation and division of elementary units—the cells."

He capitulates the principles of their theory as follows:

"1. The multicellular body is a colony or a state of cells.

"2. The cell is a unit—an elementary organism.

"3. Differentiation is caused by specific adaptation of originally like cells to different external conditions.

"4. The body is enabled to perform its work by the principle of division of labor among the elementary units. (Zellenstant.)

"5. The cell leads a double life, an independent life on the one hand, and as an integral part of a higher unit on the other.

"6. The cell limitations are the specific structure of the cell.

"7. The structure is the fundamental principle upon which all the life phenomena are based.

"8. The division of cells is caused by overgrowth over a maximum size."

Dr. Graf also speaks of the idioplasm theory of Naegeli, Weissman, and especially of Whitman, and says this theory is based upon the assumption of a formative power, the seat of which lies in the idioplasm, respectively in the idiosomes, and capitulates the theory as follows:

"1. The body of an absolute unit. Its constituents, the idiosomes, are not independent units, but are the integral parts of a whole.

"2. The cell is merely a structure, an outward sign of subtle changes in the idioplasmic constitution.

"3. With regard to the problem of differentiation, it is localized specialization, it is the grouping of idiosomes of like character into areas of increased energy."

Dr. Graf says:

"This would lead us back, however, to the cell standpoint, as it is the same thing whether we call a cell a centre of energy, an area, or a cell.

"4. The body is enabled to perform its work by a specific formative power of its own.

"5. The cell leads an independent life. The actions of the cell are due to the energies of the idiosomes. Life is the formative power of the idioplasm,

and the cells are only a result of the action of this power.

"6. Cell boundaries are of no import. Organic cohesion goes through the whole body.

"7. Structure is fundamental, is inherited, and without the presupposition of structure no function can be conceived.

"8. Organic growth and regeneration are due to the formative power of the idioplasm.

"9. The fission of cells is a secondary phenomena, is the outward sign of subtle occurrences in the idioplasm."

So much for the idioplasm cell theory.

Dr. Graf says further of another theory:

"A complete revised cellular theory, which has not been specially formulated as such, but of which we find the building stones of almost every modern cytologist since Schwann."

As for himself, Dr. Graf says:

"1. The body is an association of cells.

"2. The cell is the physiological unit, and consists of a large quantity of structural elements which may have the form of granules (microsomes). These microsomes are not all alike, but we must assume a great number of different categories of such, differing by a specific irritability with regard to external stimuli.

"Under the influence of specific stimuli, certain of the microsomes grow and divide, others remain undisturbed, and by the numerical supremacy of one or more categories of microsomes over the other the specific character of the cell is determined.

"The sum total of the energies of these granules, microsomes, or, better, biosomes, constitutes the life of the cell.

"In my view the biosomes (granules) (microsomes) cannot be imagined to live separately; they are not bearers of life but elements of a living body.

"These biosomes represent an organic association which we call a cell, and cannot be imagined separate from the association and yet living, as life is a collective conception.

"The association of biosomes called a cell is the ultimate organic unit, as the molecule is the ultimate chemical unit of a specific substance. The cells are the molecules of the body.

"The cause of differentiation might be called the selection of stimuli from the side of the cell elements. The division of labor is no formative principle or cause, but only the effects of differentiation. Thus, differentiation determines the character of the cell.

"The cell leads only one life—an independent life."

Dr. Graf maintains a perfect individuality or inde-

pendence of the cellular life in opposition to all the other cell theories. He says:

"Organic growth and regeneration are due to the growth and division of the idiosomes, which, again, is caused by the influence of the specific stimuli.

"All division may be due to the overabundance of elementary units or biosomes, and it is affected by an equal distribution and arrangement of these units into two new systems."

CHAPTER IX.

THE PHYSIOLOGICAL INTER-RELATION OF THE CELLS. BY DR. EDMUND B. WILSON, OF COLUMBIA UNIVERSITY.

In his discussion of the physiological inter-relation of the cells, Dr. Wilson reviews the whole cell theory history and its facts established up to now by the leading scientists. He says:

"The cellular structure of animals and plants was dimly perceived two centuries ago by those pioneers of microscopic research, Leeuwenhoek, Malpighi, Grew, Hooke, and their followers.

"The story of the foundation of the cell theory, by Schleiden and Schwann, in 1839 and in 1840, of its development by Remak, Koelliker, Naegeli, Virchow, and other investigators of their time, has often been told, and the history of the discovery that led to the identification of protoplasm as the physical basis of life and of the cell as the immediate arena of its manifold activities.

"Microscopic research brought to light the wonderful fact that the cell is not only the seat of vital activity, but is also the seat of heredity transmission;

and, further, that the life of successive generations of living beings show no breach of continuity, but forms a continuous vital stream, which, as Virchow says, 'rules an eternal law of continuity.'

"The physiological inter-relation of the cells bears more directly upon the general problem of life.

"Schwann, the father of the cell theory, conceived the multicellular body as a composite or mosaic work, as a congeries of coöperating but still independent units, namely, the cells. He said: 'The whole organism subsists only by means of reciprocal actions of the single elementary parts.'

"There are some forms of cells, such as the wandering leukocytes, that seem, in fact, to lead an almost independent existence in the body, their life being strikingly similar to the free-living, one-celled organisms, such as the rhizopods. Even the cells of the fixed tissues often show a high degree of independence, and may perfectly retain their individual characteristics if transplanted to another part of the body, or even grafted upon another organism.

"Whether we conceive the cell as a complex mixture of molecules, a composite of micellæ, or congeries of invisible, self-propagating units, we encounter the same problem.

"Chemical analysis proves that the protoplasm is not a single chemical substance, but a highly com-

plex mixture of highly complex organic compounds, which undergo continual chemical transformations. Indeed, the living cell is doubtless the arena of the most complex chemical operations taking place in nature.

"But the more complex these transformations the more imperative becomes the assumption of a coördinating factor that determines their orderly sequence and coöperation in the ever-recurring cycle of life. It is a similar factor that must be recognized as the coördinating and unifying element, which brings out a typical result in the development of the many-celled organisms from the egg, or its regeneration from a fragment of its own body.

"To many naturalists this is the most characteristic and most difficult of comprehension.

"Regarding the nature of that factor, we are still almost wholly ignorant, and can only say, vaguely, that it lies in the inherited organism of the same kind, developing under similar conditions. In the adult body we perceive the organization like that of a machine destined to perform specific operations, and physiological research has given us a tolerably clear comprehension of the manner in which the machine performs many of these operations. When we turn to those subtler operations involved in the cell activities, particularly in the case of germ cells, and the

developing organism, we find ourselves almost wholly in the dark.

"So difficult is it to conceive these activities by the assumption of machine-like organization of the cell, that Driesch, one of the foremost leaders of the experimental embryologists, has recently expressed the conviction that we must assume the existence of a determining and coördinating factor, or group of such factors (specifically in the egg cell and the developing embryo as a whole), for which no analogue exists in the organic world.

"It is a happy augury for the future of biology that it is apparently entering upon a new constructive phase, characterized by a frank recognition of ignorance, by a decline of baseless theorizing, by steadily increasing thoroughness and range of observation, and, above all, by the extensive application in every direction of exact experimental methods to subjects which have hitherto hardly been approached along this path.

"One of the most fundamental results thus far obtained by cell research is that the nucleus plays some essential role in the synthetic cell process, involving not only the chemical operations of constructive metabolism, but also the consideration of growth and other factors of morphological (as opposed to chemical) synthesis.

"Virchow generalized the phenomena of cell origin, and later researches have sustained the conclusion that every cell arises by division of a preëxisting cell, and in no other way. This involves not only the protoplasm mass as a whole, but also the nucleus. The nucleus is not formed *de novo*, but arises by the division of the nucleus of the mother cell. From this it follows that every nucleus of the body is a descendant of that of the egg, which, in its turn, is derived by a division of a nucleus in the parent body.

"Upon what does the power of cell division depend?

"From the investigation of this question a number of scientists arrived at the assumption of ultimate protoplasmic units, or elements, that are not single molecules, but groups, perhaps very complex molecules.

"This conception was first systematically developed by Herbert Spencer in his acutely reasoned hypothesis of physiological units. Elaborated and raised to a working hypothesis by the botanist Naegeli, who considered that the phenomena of growth are only explicable under the assumption that the protoplasm consists of molecular groups, or 'micellæ,' surrounded by layers of water.

"This assumption appears in a vague way in Darwin's pangenesis, but was first synthetically

developed by de Vries and Wiesner, and still further expanded by Weissmann.

"The power of protoplasmic growth as sought in the power of cell division is explained as follows:

"It has been seen that the cell does not simply divide as a whole, but through the separate division of nucleus and protoplasm. Nor does the nucleus undergo a mere mass division, but resolves itself into dividing units of a lower order, namely, the chromosomes. Research has shown that in some cases at least the chromosomes themselves are compound bodies, consisting of still smaller masses arranged like beads on a string, which in their turn divide, and this forms the splitting of the chromosomes.

"These smallest visible dividing elements are of extreme minuteness, and it is only a matter of conjecture whether they in turn consist of bodies smaller still. There is no reason to place the limit of this series at the point where it vanishes from view, and we are almost driven to the conclusion that the division of the nuclear substance as a whole must be the result of division on the part of invisible elements, by the aggregation of which the visible structures are formed.

"A similar conclusion has been reached in the case of protoplasm, or the extranuclear part of the cell. But the evidence here is less convincing. The pro-

toplasm of some forms of cells contains minute bodies that multiply by division ('plastids'), and a remarkable body, known as the 'centrosome,' the nature of which is now under active discussion.

"The cell, like the organism at large, maintains a state of moving equilibrium with the environment, and continually receives chemical and physical stimuli from the latter, and continually responds to those stimuli by modes of activity, conditioned by its own organization.

"This conclusion leads to the consideration of the discovery relating to the fertilization of the egg, with which the modern era of cell research may be said to begin.

"This discovery was made by Oscar Hertwig in 1875, in the egg of the sea-urchin, and has been confirmed by innumerable subsequent observers in animals and plants representing almost every known group.

"The essential fact is that the fertilization of the egg is thus accomplished.

"A single cell derived from the father (spermatozoön) unites with a single cell (the egg) derived from the mother, while the paternal nucleus unites with the maternal. By continued division of the single cell thus formed arise all the cells of the body.

"Examining the process, we find one remarkable

difference between egg and spermatozoön, namely, that while the two contribute equally to the nucleus of the fertilized germ, the whole, or very nearly the whole, of the remaining cell substance (protoplasm) is supplied by the egg.

"We have thus a substantial basis for the conclusion that the protoplasm of the embryo is derived wholly or mainly from the mother, while the nuclei are derived equally from both parents. This result, with those derived from microscopic vivisection, give for the first time a clear though superficial view of the mechanism of inheritance.

"The studies of Darwin, Galton, and others have shown that there is no peculiarity of structure or function in any part of the body too slight to escape the influence of either parent, or both, by inheritance. The physical correlative of this conclusion lies in the fact that the cells, of which every part of the body is built, contain nuclei derived by unbroken descent from a nucleus that is equally of paternal and maternal origin.

"Upon this fact Hertwig and Strausberger based the conclusion that the nucleus must be regarded as the vehicle of inheritance.

"We are thus enabled to form some conception, however imperfect, of the manner in which both parents affect the whole development of the child,

and may exert an influence upon every detail of its organization.

"Van Beneden, the great Belgian observer, building upon the basis laid by Flemming, Hertwig, and Strausberger, in 1885 to 1887, followed in detail the transformation of the nucleus itself during fertilization. His experiments were made with the highly favorable egg of the Ascaris, a threadworm parasite, in the horse.

"His discoveries, confirmed and extended by Boveri and many others, have been found to hold good to such an extent that there can be no doubt of their general applicability throughout the plant and animal kingdom.

"As the paternal and maternal nuclei approach each other within the egg, each undergoes a complicated metamorphosis, and finally resolves itself into a number of rod-like or worm-like bodies, known as the chromosomes, which are exactly equal in number and similar in form in the two.

"At this period, therefore, the egg no longer contains two nuclei, but in their place two precisely similar groups of chromosomes, which are, respectively, paternal and maternal in their origin.

"As the egg undergoes its first division to form the first two cells of the embryo, every chromosome in the group splits lengthwise into exactly similar halves,

which separate and pass one to each of the daughter cells. Each of the latter, therefore, receives two similar groups of daughter chromosomes, paternal and maternal, which are exactly duplicated in the other cell. And from these two groups in each cell is built a daughter nucleus, shown by its mode of origin to be equally derived from both parents.

"At the second division the chromosomes reappear, again split lengthwise, and the halves are again equally distributed to the daughter nucleus, and so on throughout the entire growth of the animal.

"Even before Van Beneden's work, Flemming and Strausberger had observed the formation and the splitting of the chromosomes in the division of the tissue cells (karyokinesis or mitosis). And later observers have demonstrated that this is a phenomenon of general occurrence.

"One remarkable fact has fixed the attention of all later observers, namely, that the number of chromosomes is always the same in given species; and, further, in sexually produced organisms this number is always an even one; for example, there are twenty-four in the lily and the frog, sixteen in the onion, thirty-four in the snail, thirty-six in the shark, and so on.

"In the light of Van Beneden's work, the even number of chromosomes seems only explicable under

the assumption that they are the direct descendants of those in the fertilized egg, and the latter are necessarily even, since equally derived from two parents.

"We have strong ground for the conclusion that all the nuclei of the body are equally derived from those of the two parents, and this has received support from a large number of experimental research.

"Among the foremost results recently attained in cell physiology and experimental embryology is the recent discovery of Loeb, that the egg may be fertilized by chemical stimulus without participation of the male element.

"The way for Loeb's discovery was paved by the experiments of Richard Hertwig and Morgan, who showed that if unfertilized eggs be treated by a weak solution of various substances, such as sodium chloride, magnesium chloride, or strychnine, they undergo some of the preparatory changes of division; and Morgan showed that they might actually divide, though without producing any embryo.

"The experiments of Herbst in particular gave an almost startling revelation upon the profound effect upon the egg produced by apparently insignificant alterations in the chemical environment.

"If, for example, the egg of a sea-urchin be allowed to develop in sea water containing a very slight excess

of potassium chloride, the development is greatly altered, no skeleton is formed, and a larva results which, though living and vigorous, is widely different from the normal ones

"If, in the place of potassium chloride, lithium chloride be added to the water, the changes are still more remarkable—the embryo never enfolding the cells which normally give rise to the alimentary canal, and developing, as it were, inside out. These monstrous forms are, of course, incapable of nourishing themselves, and ultimately perish.

"These decisive experiments show that the egg is capable of complete development, without union with the spermatazoön, as a result of chemical stimulus, and they also indicate that even in normal fertilization we must regard the stimulus and development as being given by a specific substance, or substances, carried by the spermatazoön.

"It has long been known that the eggs of a number of animals—plant lice and some crustaceans—are capable, under certain conditions, of developing without fertilization, *i. e.*, by parthenogenesis; and it is probable that here, too, the stimulus may be due to changed chemical conditions affecting the egg through the process of nutrition.

"Loeb's further experiments, together with slight earlier ones of Herbst, indicate that the normal

equilibrium of the egg depends upon the equilibrium of chemical conditions in the protoplasm which is maintained by the conditions of the environment."

SOME PHASES OF MENDEL'S FAMOUS LAW OF DOMINANCE AND SEGREGATION AS IT HAS BEEN APPLIED BY SOME SCIENTISTS TO SEX-DETERMINATION THEORIES.

Mendel's principles of heredity in his law of dominance and segregation are considered by some scientists as perhaps the greatest discovery ever made in the study of heredity. And it seems almost certain that a number of the more popular modern sex-determination theories have been constructed directly or quite obviously indirectly upon this famous law.

The basic principles of Mendel's law are two—(1) that of dominance, and (2) segregation. As explained by William Ernest Castle:

"The principle of dominance: When there unite in fertilization two gametes, one of which bears one of a pair of alternative characters, while the other gamete bears the other character. It often happens that the zygote thus formed manifests only one of the two characters. This character may be called the dominant one.

"The other character becomes latent or recessive, and is first seen in the next generation of offspring. For example, when white mice are crossed with wild gray mice, all the offspring are gray, that character being dominant; white, recessive.

"White mice are never obtained in the first hybrid generation, but upon breeding of the primary hybrids both white and gray offspring are obtained, approximately in the ratio of 1 to 3.

"The principle of segregation: The appearance of white mice as just described in the second hybrid generation follows the principle of segregation.

"The primitive germ cell of the primary hybrid contains both parental characters, *i. e.*, dominant and recessive, but in the maturation of the germ cell the two are separated, so that the ripe germ cell, or gamete, contains either dominant or recessive, but not both."

This is the part of Mendel's famous law which is supposed to be applicable to sex determination. Professor Kellogg, of Stanford University, California, says Mendel's name will undoubtedly live forever in the annals of biological science. For the observations, experiments, and conclusions of Mendel on inheritance have taken their place already as matters of fundamental importance in the study of heredity.

George Johann Mendel was an Austrian monk,

whose parents were peasants. He lived in the small Austrian village of Brunn, was ordained a priest, and became Abbot of his cloister. It was some time between 1855 and 1865 that in the garden of his cloister he carried on the culture of peas and other plants. The data that he thus acquired he read before the Natural History Society of Brunn, together with his interpretation of their significance. In 1865 he published the account of his experiments and studies, under the title of *Experiments in Plant Hybridization*. He spoke of himself as a student of Collar, and was for a time made president of Brunn's Natural History Society.

PART III.

SYNOPSES OF A NUMBER OF POPULAR SEX-DETERMINATION THEORIES BY LEADING SCIENTISTS, WITH AN ANALYSIS AND VALUATION OF THEIR PRACTICABILITY ACCORDING TO OTHER PROMINENT SCIENTISTS OF TODAY.

CHAPTER X.

A THEORY OF SEX DETERMINATION, BY WILLIAM ERNEST CASTLE, OF HARVARD COLLEGE.

"I would go farther, and say that all animals and plants are potential hermaphrodites, for they contain the character of both sexes. Ordinarily, the characters of one sex only are developed. The existence of each sex, in a latent condition, in all creatures is shown by the occurrence in each sex of the rudimentary organs peculiar to both sexes."

Of Mr. Castle's theory of the dominance in some eggs of the female element, and in others of the male element, he says:

"Our present knowledge of the process of fertilization indicates that in it a union is accomplished between elements strictly equivalent to those which separated in the formation of the gametes. But we should expect only opposite sex characters to unite in fertilization. The male and the female characters meet anew in a struggle for supremacy at each fertilization. Sometimes one and sometimes the other dominates in the zygote, and the vanquished character becomes recessive."

Mr. Castle undertakes to substantiate his theory of sex determination by Mendel's principles of heredity in his law of dominance and segregation. Mr. Castle says:

"Accordingly there are ova 'dominant' and ova 'recessive' possessed by each parent in equal abundance, and they unite at random, the sorts of zygotes resulting, and their relative frequencies of occurrence will be expressed by the product."

Mr. Castle thus locates the sex of the offspring in the germ cell of both parents to be determined, according to Mendel's principles of heredity in his law of dominance and segregation.

The following is a short review of Professor T. H. Morgan's analysis and valuation of Mr. Castle's theory of sex determination.

"Castle has also recently advanced certain hypotheses in regard to sex determination.

"In certain superficial respects Castle's views appear similar to those of Beard, but closer scrutiny shows that the two views are essentially different in many important points.

"Castle assumes that there are two kinds of eggs, male and female, and two kinds of spermatozoa, male and female. He supposes that both kinds of spermatozoa are functional in the sense that each carries with it the possibility of determining the sex

of the individual, and that each spermatozoön is also capable of fertilizing an egg; but a male spermatozoön can fertilize only a female egg, and a female spermatozoön can fertilize only a male egg.

"It is evident, therefore, that Castle's idea in regard to the spermatozoa fundamentally differs from that of Beard. Furthermore, Castle supposes that the separation of the male from the female qualities of each egg takes place at the time when the second polar body is extruded, and, in consequence, the egg and one of the polar bodies will be female, and the other two polar bodies male; or, if the egg remains female, one polar body will be female and the other two male. Similarly, for the spermatozoa, two of each four (formed from the spermatocyte) are female and two are male.

"Perhaps the most distinctive part of Castle's paper is his attempt to apply the much discussed Mendel's law to problems of sex determination—an idea that had suggested itself to Batesson and Saunders, but had been rejected, because the distribution of sex among first crosses shows great disparity from the normal proportions. Castle does not admit, however, the force of this objection."

Professor Morgan then cites the example of the crossing of the wild gray mouse with a white mouse, and says:

"Castle tries to make an application of Mendel's principles of heredity to sex.

"Just as there are two kinds of mice, in our illustration, white and gray, there are two kinds of sexual individuals, male and female.

"It is now assumed that the germ cells, when they reach final division, separate their male from their female, giving pure male and pure female eggs, and pure male and pure female spermatozoa.

"If, as in the mice, all chance combinations of the germ cells are possible, there will result three kinds of individuals, in the proportion of 2: 1: 1.

"The first of these, that are twice as common as either of the other two, would be sex hybrids.

"If we assume, as in the mice, that one character always dominates in such a combination, the male, let us say, there would be twice as many males of this hybrid kind as there are individuals of either of the other two pure kinds; and since there are as many pure males as there are pure females, there would be in all three times as many males born as females. Since we know there is no such disproportion of one sex to the other, it appears absurd to attempt to apply Mendel's law to the problem of sex.

"Castle is therefore obliged to make a further assumption to avoid this difficulty.

"He assumes that a male spermatozoön can fer-

tilize only female eggs, and a female spermatozoön only male eggs.

"There is no evidence known at present supporting this assumption, but it must be admitted that it cannot be disproved, however improbable it may appear.

"On this view every fertilized egg is a sex hybrid, and may give rise to a male or to a female, according to which elements dominate.

"Thus we return once more to our original question, as to what determines the sex of the individual.

"We shall see presently that Castle fails to meet this fundamental question.

"There is another side of Castle's hypothesis that must be briefly referred to, since he suggests a way of meeting a difficulty that is fatal to Beard's theory. I refer to parthenogenetic development and to the production at the end of a parthenogenetic series of male and female individuals.

"Castle supposes that in parthenogenetic reproduction the female character dominates over the male, when the two are present together, and that when a separation of the sex characters takes place it does so at the time of the formation of the second polar body in the egg, and probably at the corresponding state of development in the spermatozoön.

"There is a fact in this connection the bearing of

which Weissmann was the first to fully appreciate—namely, that the parthenogenetic eggs of daphnids and of some rotifers give off only one polar body, while eggs that are to be fertilized give off two polar bodies.

"Castle suggests that the second polar body is the female gamete, hence, when it is given off, the egg must become a pure male if it develops. If this polar body should be retained in the egg, the conditions are exactly the same as when a female spermatozoön enters a male egg. Hence, since the female element dominates in these animals when the two sexes meet, the individual must become a female.

"Since, therefore, such an egg carries the male element in a recessive form, this element may, if it becomes separated from its female associate, give rise to a male. In this way the theoretical difficulty referred to above is met.

"Castle's theory appears needlessly complex, and the whole attempt to apply the Mendelian principles to the question of sex does not appear to have been successful. The weakest side of the theory has already been spoken of—namely, that it fails to account for the very problem that a theory of sex should explain—that is, the problem of what it is that determines whether an egg that contains both potentialities becomes a male or a female."

To the assumption that there are male and female eggs, and male and female spermatozoa, Professor Morgan says:

"We have just examined two recent theories that rest on assumptions of this kind, and have found, in my opinion, that they are both unsatisfactory."

CHAPTER XI.

VIEWS ON SEX DETERMINATION, BY M. L. CUÉNOT, OF NANCY, FRANCE.

"As to the time at which the determination of sex is irrevocably settled in the embryo, there are four theories held by leading scientists of the world:

"1. A group who believe that the sex of the embryo is determined before fertilization, and consequently without any influence of the male. Among this group are Ahlfeld, Schultz, Anazagore, Coste, Henke, Seligson, etc.

"2. Those who believe that the determination of sex is at the moment of fecundation. Among these are Democrite, D'Abdere, Aristotle, Thury, Richartz, Lesshaft, Mayrhofer, etc.

"3. Those who believe that sex is determined after fecundation, influenced by the conditions of gestation, and, consequently, without the participation of the male. Among these are Empedocle, Ackermann, and Geoffroy-Saint-Hilaire.

"4. Those who believe that sex determination may be at any time, before, during, or after fecundation. Among this group are Dusing, Wilckens, and Orshansky."

M. Cuénot says that, of these theories, the third must be eliminated at once as impossible and unthinkable. Then he discusses the three remaining theories:

"1. Ahlfeld's theory claims that the male and female eggs develop in the ovary, and that the father has no influence whatever upon the sex of the offspring, but that it is entirely with the mother."

Apropos of Ahlfeld's theory, Simon Newcomb says:

"The question of the influence of the age of the parents has been studied by Rosenfeld, Saddler, and Bertillon. Saddler laid down the general law that the elder parent has preponderating influence in the direction of determining children of his or her own sex. But Ahlfeld reached the opposite conclusion, that when the father was more than ten years older than the mother there was a preponderance of female children."

"2. This group, including Aristotle, de Gelien, and others, believe that the human spermatozoön is in its nature male and female, and that the mother has nothing whatever to do in the determination of the sex of the child.

"3. Dusing declares that a quantity of factors influence the sexual development of the egg and spermatozoön from their first appearance in the child's developing genital glands, their maturation, and

subsequent fertilization, and besides this, there are other factors that affect the sex developed in the embryo up to the very moment when the character of the sex of the embryo is apparent as either male or female."

The following is the theory preferred by M. Cuénot himself:

"Sex is determined at the moment of fertilization, as a result of the conflict of the two gametes—maternal and paternal—and nothing can change their character of male and female, once established, during the course of their development. Each of the gametes is influenced by several factors (dont la somme algébrique déterminé la tendance finale)."

M. Cuénot explains at great length why he prefers this theory to any of those cited above, especially for mammals. In regard to the conflict of the gametes, it will be remembered that Castle says:

"The male and female characters (gametes) meet anew in a struggle for supremacy at each fertilization; sometimes one and sometimes the other dominates in the zygote, and the vanquished character becomes recessive."

M. Cuénot discusses sex determination under three heads, in the light of other experiments which were submitted to him for consideration, and from his own experiments: (1) He discusses notions acquired

regarding the best-known forms of parthenogenetic life, since the determination of sex with them is necessarily different from animals that require fecundation. (2) Notions acquired regarding the different groups of creatures—"a fecundation boligatoir"—in the light of ancient research as well as from his own experiments. (3) A general discussion, where he examines the various problems raised by the question of sex determination, especially regarding autoregulation, époque, participation des parents, sexe des bourgeons, hermaphroditism, etc. Under the first head he deals with rotifers, daphnids (fleas, water lice), aphids (plant lice), cynipides, and hymenoptera porte aiguillon. Some of his conclusions under this head are:

"The quantity and quality of nutrition does exercise an effect upon the eggs in the ovary of the mothers of these orders of life—developing an especial sort of males and females."

With regard to the effect of spermatozoön upon the parthenogenetic egg, he found:

"The unfecundated egg that produced a male, when fecundated, produced a female, and that in all cases that the sex of the creature was determined in the egg which gave it birth, not later than the moment of fecundation."

Under the second head he considers the classic

examples of pigeons, insects, and frogs, and again concludes:

"The determination of sex coincides with the moment of fecundation or before it."

As to nutrition, he cites Marchal's observation, that insects poorly nourished produce male offspring. But as for his own experiments on this subject he says:

"My experiments gave altogether different results from this. While nutrition of the parents does not play the role of sex determination, at the same time it is a significant fact that a poorly nourished creature produces few eggs, and one abundantly nourished produces many; but in both cases the usual proportion of sexes appears.

"As to the effect of the age of the spermatozoön as a determining factor of sex, is the classic example of the pigeon, which, since the days of Aristotle, has been supposed always to lay first a male and then a female egg.

"Those who believe this argue that the second egg is fertilized, by at least a few hours, by an older spermatozoön than the first egg; that in that probably lies the determination of their different sexes.

"Gerbe pretends, after careful experiments, that a hen, for fifteen days after a single fecundation, produces fertilized eggs.

"Also Girard, Joseph, and Brocadello found that the size of the egg is a sexual difference, and also this is the verdict of fowl raisers. My own experiments do not contradict this.

"My own experiments, as well as those of others, only verify for me that the sex of the egg is determined in the egg, and not later than fertilization."

In the second part of this second division of his subject Professor Cuénot examines the theories of sex determination as regards human beings and other mammals. He says:

"The determination of sex is one of the most interesting and most difficult problems of biology. From the greatest antiquity, the solving of this problem has been sought for, but no satisfactory solution has yet been found—not one that has been able to stand the test of time. Modern science has been able to solve this problem for a few of some of the inferior forms of life.

"It is humiliating to be obliged to admit that for mankind and other mammals there has not been much advance since the time of the predecessors of Aristotle, although there has been a considerable amount of hard work done—il faut croire qu'on s'y est mal pris.

"It is something to be able to demolish others' theories, but in order to be able to build up solidly

this matter, it is necessary to establish these fundamental points: When is sex determined, and what the influence of the parents, the one or both, which can stand the crucial test of experiment?

"Then Professor Cuénot speaks of various ideas that have formed the basis for different theories on the subject, among them the following:

"Age of parents: Some say that a very young or a very old father has but little power to transmit their sex to their offspring. But this is not apparent in the actual facts of life.

"Social Conditions: Investigation shows a very small variation in the sex of the children of well-to-do people and the poor; between the aristocrat and the peasant; and that of the clergy.

"Nutrition as a Factor: Nearly all investigators attribute an enormous importance to the quantity and quality of the parents' nutrition; indeed, nutrition has become a classical subject for proof of sex determination.

"Dusing bases his theory of the law of natural selection as applied to sex upon nutrition, pretending that with abundant nutrition organisms produce more females, because that is an important factor for the preservation of the species, and that with meager nourishment males are produced.

"But in the case of twins, Dusing must admit that

two children would have less nourishment from a single mother during the developing of the embryo than a single or one embryo would have, and yet that the sex of the twins is almost as frequently different as they are identical. And that this is true of triplets, where, also, again, the nutrition is divided between three instead of one, and yet they are not infrequently all girls.

"While Fiquet and Richarz found that a parent well nourished transmitted the sex contrary to his own, which is the basis for the theory for cross-heredity as a factor in the determination of sex."

As for himself, Professor Cuénot says:

"Good or poor nutrition of the parents has a positive influence upon the sexual tendencies of the maternal and paternal gametes, but it must be administered before the moment of fecundation."

Of Schenk's theory, which has its basis in nutrition, he says:

"Schenk's theory, recently promulgated, which has made considerable noise, especially in the world of 'extra scientifique,' is: If, in a mother's urine, there is found a certain quantity of sugar, which indicates an incomplete combustion of carbon hydrates, the maturing egg, affected by this, becomes female; if there is no trace of sugar, the egg becomes male."

After undertaking to verify all the known data on

the following subject as a sex determining factor, Professor Cuénot says:

"Je ne crois pas utile de parler de la proportion sexuelle considerée dans ses reports avec une faible ou forte menstruation, avec un bassin étroit; no more than with the month of the year, the high altitude of the country, the consanguinity of the parents, or of the sickly condition of the one or the other.

"It appeals to me as superfluous to speak of such fairy tales and fables, proposed by a considerable number of writers on this subject, who are as highly imaginative as they are little scientific.

"It is therefore evident that sex is determined by internal factors about which we have not the slightest knowledge, for external circumstances could not influence the determination of sex only in the most indirect and remote fashion.

"Not only will human beings probably never be able to voluntarily control the sex of their children, but, also, they are unable to predict, depending upon external circumstances, with any degree of certainty, the sex of an unborn child."

Under his third head of general discussion Professor Cuénot takes up the subject of twins:

"Among human beings there are two kinds of twins. In the first category each one of the twins has its own particular chorion; the placentas of these

twins may or may not have vascular connection. It is believed that these twins come from two different eggs, each fertilized by a separate spermatozoön and developing side by side. And these twins are frequently of different sex, averaging about thirty-six out of a hundred.

"In the second category, to the contrary, the twins are enclosed in the same chorion, have a single placenta for both of them, and it is believed that they come from a single egg, and always, without a single exception, the twins are of the same sex.

"Many think that in this case the egg has two germative vesicles. But I think that that is not necessary, but rather that the blastoderms of the egg are separated.

"As a result of convincing observations, it is generally believed that the two gametes have an equal participation in determining the sex of the egg, which is contrary to the hypotheses of Schultz and Ahlfeld."—*Bulletin Scientifique de la France et de la Belgique*, October, 1899.

CHAPTER XII.

THEORY OF JOHN BEARD.

"1. The sex of the individual is determined in the egg before fertilization.

"2. The determination of sex probably takes place at the time of the reduction in the number of chromosomes.

"3. Each egg and its two polar bodies are potentially of the same sex—either male or female.

"4. A corresponding differentiation of the primary germ cells takes place in the male. An early separation of the spermatogonial cells into male and female occurs. After this each cell may continue to divide, but remains of the sex it has acquired in the differentiating division. Finally, each of these cells produces four spermatozoa. This division is comparable to the one in the egg series when the polar bodies are given off, so that each group of four spermatozoa corresponds to a female egg and its three female polar bodies; but in the cases of the spermatozoa, the individuals are supposed to be without sexual qualities. It is the egg alone that determines the sex."

In regard to Beard's theory of the sex problem, Professor Morgan says:

"Beard attempts to bring the differentiation of the sexes into connection with the recent work relating to the origin of the reproductive cells or gametes.

"He appears to take it for granted that a female egg can give rise to cells that become male eggs. If so, this theory can have very little if any value, since the entire conception upon which it rests, namely, the separation of the male and female eggs at one division, is rendered valueless, I think, by the assumption that after such a thing has taken place a female cell may in the next generation give rise to male eggs.

"Furthermore, Beard's assumption that the separation of the male and female egg occurs at the time when the reproduction in numbers of the chromosomes takes place in the egg is pure guesswork, and not very good guessing either, for certain recent work indicates that the reduction in the number of the chromosomes involves a process that can have no conceivable connection with the separation of male from the female elements of the egg. On the whole, it does not appear that Beard has offered a very convincing theory as to how the determination of the sex of the individual is accomplished. He tries to show that there are not only two kinds of eggs, but also two kinds of spermatozoa that correspond to the two kinds of eggs. That the determination of sex rests entirely in the egg, and that the spermatozoa

do not have any influence on sex determination, and that one of the two kinds of spermatozoa has lost its power of fertilizing the egg, and in most cases has become degenerate.

"In respect to the occurrence of two kinds of spermatozoa, it has been known for some time that in a few cases two kinds of spermatozoa have been found. In the long list of cases given by Beard, in which two forms of spermatozoa have been described, there are several cases in which the two distinct forms appear to be always present and characteristic, as in the cases cited. He also includes other cases in which giant spermatozoa occur, and some of these at least have been shown to be the result of a failure of the spermatocytes to divide.

"Until it can be shown that this failure to divide is usual and characteristic of one set of these spermatocyte cells, the result may really have no bearing at all on Beard's contention.

"Much more striking are the cases in which there is an accessory chromosome present in two of the four cells that develop from a single spermatogonial cell.

"The discoveries of McClung, Montgomery, and Sutton in this connection indicates that there are two kinds of spermatozoa, and McClung has urged that this difference is connected with the determination of

sex. But there is nothing more than the supposition that this may be so.

"In these cases, although the form of the spermatozoa is the same for the two kinds, there appears to to be a difference in the amount of the chromatin material.

"It has not been shown that a difference of this kind would have any value in the determination of sex, and even if this were the case, the results do not conform to the requirements of Beard's theory.

"He calls attention to the fact that in nearly all the cases in which two kinds of spermatozoa have been described there is evidence of the degeneration of one of the two kinds. From this he draws the rather sweeping conclusion that throughout the animal kingdom one of the two forms of spermatozoa has been suppressed. He arrives at this conclusion in the face of an overwhelming body of evidence to the contrary, for in the great majority of forms all the spermatozoa that are formed develop in the same way, and are, so far as we can see, capable of fertilizing the egg.

"In a sense, Beard took up the sex determination problem where it was left by Cuénot."

CHAPTER XIII.

VIEWS ON SEX DETERMINATION, BY PROFESSOR T. H. MORGAN.

"1. It has been shown in several cases by recent discoveries that the sex of the embryo is already determined in the fertilized egg. In other cases it appears to be determined even before fertilization, but this need not mean that there are male and female eggs and male and female spermatozoa.

"May it not be possible to bring under one point of view the old and new discoveries in regard to the determination of sex, and construct an hypothesis that does not involve the idea that there is separation of the primoidia of sex in the germ cells?

"It has been shown in a few cases that two kinds of eggs are produced, which become male and female individuals, in some cases with fertilization, in others without fertilization.

"It may be erroneous to conclude from these facts that the eggs themselves are male and female in the sense that the elements (primoidia) that determine the sex of the embryo have become separated and confined to the male or female eggs.

"In a case like that of the silkworm, where a graded series exists, the size of the egg appears to be the determining factor in respect to which sex develops, not that the female sex elements are found only in the large eggs and the male elements in the small eggs. It seems more reasonable to assume, on the contrary, that both elements are present in all kinds of eggs. In other cases other factors than that of size determine which sex develops.

"In regard to the two forms of spermatozoa that have been found in few species, there is no evidence that one sort contains only the primoidia of a male individual and the other those of the female.

"In those arthropods in which an accessory chromosome has been found we have no evidence to show that this chromosome is the male or female element, and so long as we know nothing at all in respect to conditions in the egg, it is useless to speculate further on these cases.

"2. There is experimental evidence pointing to the conclusion that factors external to the egg itself may determine in some species what kind of egg will be produced. In other cases it appears that the addition of the chromatin in one of the polar bodies may accomplish the same result. Here the relation may be purely a quantitative one. In other animals the addition of the spermatozoön to the

egg is not, it appears, the factor that determines the sex.

"3. Having discovered that the sex is already determined in the fertilized egg in some cases, and in others that it is connected with the processes of fertilization, the question at once suggests itself whether the determining influence comes from the nucleus or the cytoplasm. At present we have no conclusive evidence pointing in either direction.

"That the quantity of nuclear material may be important seems probable in the case of the bee.

"That the size of the egg, which is due to a greater amount of cytoplasm, may be a factor in the result, seems in other cases to be important, but so long as we do not know what relation the nucleus bears to the cytoplasm in these forms we cannot decide as to the meaning of greater volume as a sex determinant.

"If, as seems highly probable, identical twins come from halves of the same egg, then, since the pairs may be of either sex, it seems to follow that the absolute size of the egg is not a factor. Whether in these cases the chromatin in the nucleus enters into the problem remains to be shown.

"It should be pointed out that while we must suppose that the influences in the embryo that control the development of one or the other sex reside, or have resided, in the nucleus of the egg, this is a dif-

ferent question from that as to whether the nucleus or the cytoplasm of the egg determines which of the two possibilities that are potentially present in the nucleus shall be awakened.

"Among the earlier experiments that were carried out to show whether the sex of the individual could be determined by external conditions were those of Born, in 1881, and of Yung, in 1885.

"Born tried to show that more male eggs developed when the fluid containing the fertilizing spermatozoa is more concentrated.

"But this conclusion has been shown to be wrong.

"Born also fed the tadpoles of Rana temporarily on a rich diet, consisting of water plants, and of the flesh of frogs and tadpoles. A large percentage of females developed, which Born attributed to the abundance of food.

"It was shown, however, by Pflüger, in the following year, 1882, that Born's conclusion was erroneous, because even under normal conditions female frogs are more numerous.

"Pflüger found that the normal proportions of females to males is often as high as five to one. This corresponds also to the proportion sometimes obtained when tadpoles are reared from eggs artificially fertilized.

"A difference is found in the size of the eggs that

produce male and female in certain rotifers, in Hydatina senta, for example. In this species there are three kinds of females, distinguished by the different kinds of eggs they lay. One lays large eggs, which without fertilization produce females. Another lays small eggs, less rich in yolk than the last, and these eggs, also without being fertilized, produce males. A third kind of female produces the winter egg, which are fertilized by the males and give rise to females.

"Nussbaum has made the important discovery that the amount of nourishment taken by a young female between the time of her emergence from the egg and the deposition of her first egg determines which kind of eggs she will subsequently produce.

"If she has been well nourished in this interval, she produces eggs that become females; but if poorly nourished, she produces male eggs.

"It has not been determined why some females produce parthenogenetic eggs and other females produce winter eggs that are to be fertilized.

"In view of the facts known with regard to the nature of some insects and crustaceans, the daphnids, or water fleas, the aphids, or plant lice, the appearance of the male and female generation is supposed to be connected with the change in temperature, or, more probably, with the change in the amount of food. Under these conditions, as has just been said,

eggs that produce males and females have been formed. Here it would appear that an external condition determines the appearance of the male and of a different kind of female."

In conclusion, Professor Morgan says:

"Our general conclusion is that while recent theories have done good service in directing attention to the early determination of sex in the egg, those of them which have attempted to connect this conclusion with the assumption of the separation of male and female primoidia in the germ cells have failed to establish their point of view.

"The egg, so far as sex is concerned, appears to be in a sort of balance state, and the conditions to which it is exposed, even when it is not fully formed, may determine which sex it will produce. It may be a futile attempt to try to discover any one influence that has a deciding influence for all kinds of eggs. Here, as elsewhere in organic nature, different stimuli may determine in different species which of the possibilities which exist shall become realized."

CHAPTER XIV.

VIEWS ON THE ORIGIN AND DETERMINATION OF SEX, BY JOHN ADAM RYDER.

"Reciprocal relations are sustained between nucleus and cytoplasm of such importance that the transformation or 'fission' of the one is impossible without the other.

"The growth of molecular bodies and disintegration is probably essentially similar to the growth and solution of crystals, during the process of metabo lism, with this difference, that growth and disintegration go on at the same time in living bodies. The forces that determine this, we may be certain, are of a chemical nature, operating under very peculiar conditions.

"Sex itself is thus determined, and must in some way depend upon subtle disturbances of the transformation of the molecular mechanism of the germ, the nature of which is quite unknown to us.

"In man the ratio of volume of the male cell to the female is as 1 to 3000, approximately. The substance of the egg appears to be complementary to that of the spermatozoön. The power within the egg

to develop a new being is not manifested without the presence of the male.

"We find that living matter is chemically the most complex and unstable substance known. It is composed largely of carbon, a quadrivalent element that stands alone in its power to contain within itself, and at the same time hold in chemical bondage, groups of atoms representing other chemical bodies. External forces can never be excluded in studying the life history of any organism. Metabolism is assumed to be the sole agent in affecting the mechanical dynamical rearrangement, or sorting, of the nucleus into organs during development.

"It is sufficient to indicate that the transition from asexuality to female microgonidia and male microgonidia is affected by mere differentiation of cells as respects their size.

"The new dominant hypothesis is simply an amplification, in the light of numerous modern facts, of the performationism of Democritus.

"He supposed that almost infinitesimally small and very numerous bodies were brought together in the germ from all parts of the body of the parent.

"These minute representative corpuscles were supposed to have the power to grow or germinate, at the right time, into the forms of the parts and the organs of the new being. In this way it was supposed that

the characteristics of the parents were represented in a latent in the germ, which might grow as a whole, by the simultaneous and successive development of the germinal aggregate composed, so to speak, of excessively minute buds, or rudiments of the organs.

"In such wise, also, did the successors of Democritus, namely, Aristotle, Buffon, Erasmus, and Darwin, suppose that the inheritance of parental likeness by offspring was to be explained.

"Dr. Spencer supposed that the germ cells and sperm cells are essentially nothing more than vehicles in which are contained all groups of the physiological units in a fit state for obeying their proclivity toward the structural arrangements of the species they belong to.

"These 'physiological units,' according to Mr. Spencer, are neither chemical nor morphological in character; but it is admitted that their properties and powers must be determined in some way by their own constitution, conditions, and aggregation, and relation to the outer world."

CHAPTER XV.

THE DEPENDENCE OF SEXUAL DIFFERENCE UPON OUTWARD INFLUENCES, BY THE LATE PROFESSOR S. L. SCHENCK, OF VIENNA.

"1. The theory of nutritious and organic exchange alone can lay claim to accuracy and validity upon the subject of influence on the formation of sex in the ovum.

"The conditions of nutrition, and especially the organic exchange of the parent individual, have an influence on the formation of sex not only among the lower animals, but also in the case of the higher species, and also of man.

"A greater capacity for the consumption of the nitrogenous substances is shown in connection with the male sex than in the case of those ova which develop into female individuals.

"Concerning the arbitrary determination of sex by means of dieting: Among the Germanic tribes from India, according to a quotation by Michael Stephanides, of Metelin, the geographer Strabo says: 'Thus by means of their medical science they were able to produce either male or female generations, affecting

this either by drugs or by the use of certain kinds of foods.'

"There are cases where the desired result is scarcely attainable by means of outward influences. In experimenting, one meets with cases in which it may be seen by the results of assimilation, even during the experiment, that there is no hope of successfully influencing the formation of sex by means of nourishment.

"In these cases a power of resistance with regard to the assimilation of food appears to be shown by which it is impossible to obtain a sufficiently large assimilation of albumin, such as is necessary to obtain a male by arbitrarily influencing the sex.

"It is conceded by Wilkins that in addition to nutrition there are other influences at work upon the determination of sex which may not have been considered, and the investigation of which has not yet been made. Hence it occurs that one and the same female generator, in the same conditions of stimulation, does not always generate the same sex—notably twins and triplets, etc.

"Since my publication a number of writers have been occupied with this question, among whom are Giovanni Canestrino, A. Gevidelli, L. Weill, of Strausberg; K. Fukii, in Tokyo, who also established the influence of nutrition; Professor Dangeard, of Poitiers, and many other scientists.

"Elements of the human ovum, which is not so accessible to chemical research on account of its microscopic size, has not been investigated so thoroughly as those of other classes of vertebræ possessing large ova. The bases of the chemical and physiological processes are found in the ovum.

"There are a number of processes which are recognizable by morphological signs, there also occur within the changes of a physiological nature, the knowledge of which is still imperfect and insufficiently studied.

"So, for example, are formed the functional power of the heart's action, of the breathing apparatus, of the intestinal canal, of the central and peripheral nerve system, of motility, etc. In all these processes, besides a number of anatomical signs to be observed, leading to the development of the permanent forms, there are certain other constantly recurring actions in the histological elements and the organs composed of these, the study of which is at present impossible.

"In this class of phenomena also belong the origin and completion of the difference of sex in the human ovum and in that of animals. In these changes taking place in the ovum it is impossible to detect any morphological or physiological sign by means of which it might be determined with certainty in the

case of the unimpregnated ovum, in the early stages of development, whether it be male or female.

"It may, however, be said with certainty that this phenomenon must be considered as inherited, and that a fundamental cause must precede this heredity.

"The heredity of sex appears to be connected with the heredity of other physiological qualities. With the preservation of the latter quality in the offspring it also happens that the one or the other sex is formed in the ovum.

"Its appearance at this time does not seem to be an independent formation of the genital regions alone.

"Those qualities of a parent which affect the sex of an ovum, such as nutrition and organic exchange, appear to be necessarily hereditary in order to produce an effect in the formation of sex by heredity.

"The ovum coincides in all conditions of nutrition with the parent, whether the former be in the earliest stage of development or in a state of maturity. Even after impregnation the dependence of the various processes of development upon the parent is not to be denied.

"As regards many animals of the inferior classes, we are in a position to testify to facts, proving that there is an undoubted influence on the formation of sex by means of nutrition.

"Observations have also been noted in the case of

higher animals, showing that scanty nutrition is favorable to the development of males.

"Ploss asserts that the proportion of male births rises and falls with the price of food.

"Rolph characterizes males as a 'hunger generation.'

"Men suffer more in times of want than the more abstemious women. Hence the greater influence of the latter on procreative action, and according to the theory of cross-heredity, more male births.

"This theory of crossed sexual heredity has long been known.

"Lorenz asserts, from his genealogical studies, that entire families appear predestined to the generation of female offspring, and that in some the tendency to male and in others to female births repeats itself from generation to generation. One also meets with the tendency of many families to produce always male or always female firstborn through long lines of descent.

"Generally speaking, it is only possible in the case of reigning families to determine which sex has predominated in succession through a long line of generations. One fact is certain, that it is only in the rarest cases that one sex occurs exclusively, without the presence of the other, if only in very small numbers.

"It may be seen from statistical reports that no case is at present known in which one sex alone is

constantly found in a line of successive generations; but there are many cases known of families in which isolated representatives of the other sex occur here and there."

THEORY OF HOW SEX MAY BE CONTROLLED, BY DR. ROMME, A FRENCH SCIENTIST.

"Sex favors the weaker parent. A weak father will have mostly boys, a weak mother a majority of girls.

"We arrive at a conclusion which may be summed up as follows: If a woman be dieted according to our method, she can reach a stage in which she becomes physically superior to the man, and her offspring will then be male, in accordance with the law of cross-heredity of sex.

"Old age is one of the weaknesses which nature favors particularly in determining sex. When old men marry young women the offspring is in a large majority of cases male. The older the husband, the greater the probability of a boy."

It has been said that Dr. Romme takes up the work on sex determination where it was laid down by Dr. Leopold Schenck, of Vienna. He gives the following prescriptions:

"The diet for the mother when a boy is desired: Eat as much meat and fat as possible, and as little

sugar and starchy foods as possible." Like Dr. Schenck, he advocates highly nitrogenous diet. "Add only so much carbohydrate as is absolutely necessary to prevent its want being felt.

"We would say that in certain regions and among certain peoples where meat forms the principal diet, a large preponderance of male offspring would be anticipated.

"Whether the mother eats much meat is a secondary consideration. Whether and how the food taken is made use of completely in the process of combustion, that is a matter of importance for the purpose we have in view.

"How the physiological combustion goes on in the organism, and what changes take place in it, in consequence of the altered diet, until sugar entirely disappears, is in the case of human beings of the highest importance and furnishes an index of the consequences."

THEORY OF SEX DETERMINATION, BY E. T. BREWSTER, 1906.

"1. Sex in man is nearly if not quite a matter of chance.

"2. In large families and among the first three births in families of six children or more the proportion of boys is more than average.

"3. This is probably due to the great vigor of the mothers.

"4. The excess of boys is not entirely due to prepotency, but it probably points to the fact that these mothers lose fewer boys than the average women.

"5. The same principle might be conceivably extended to explain all departure from chance distribution.

"If two or more children, consecutive, are of the same sex, the next stands an appreciable better than an average chance of being of that sex also.

"A sporting neighbor of the patriarch Jacob, after the birth of the eleventh consecutive son, might risk a wager of three to one that number twelve would also be a son.

"A tendency to depart from chance distribution in sex, in a direction of excess of boys or girls, is correlated with the age of the mother. The correlation need not, however, be direct. In fact, it is a more obvious supposition that the correlation is primarily with bodily vigor and only incidentally with age.

"Presumably women who bear more than five children are appreciably more vigorous than the general body of wives. They should, therefore, bear a somewhat larger proportion of boys.

"After all, the significant thing about the distri-

bution of sex is that it is so nearly in accord with chance. Only by supposing a chance distribution, somewhat modified by some variable causes acting within small limits, can we avoid the difficulties inherent in all theories which involve the idea of prepotency, and assign to the same cause the general law and the departure from it."

CHAPTER XVI.

ON THE EVOLUTION OF SEX AND SEX DETERMINATION, BY GEDDES AND J. ARTHUR THOMSON, 1889.

"It is recognized that the problem for the production of male and female is one for scientific analysis; thus, the constitution, age, nutrition, and environment of parents must be especially considered.

"The theory that there are two kinds of ova, respectively destined to develop into males or females, is more than a mere begging of the question.

"The constitution of the ovum is undoubtedly a fact of primal importance, but we must also recognize that what is virtually decided at this early stage may be counteracted by later influences of an opposite character.

"Males live at a loss, are more 'katabolic'—that is, disruptive changes tend to preponderate in the sum of changes in their living matter, or protoplasm. Females, on the other hand, live at a profit, and are more 'anabolic.' Constructive processes predominate in their life, whence, indeed, the capacity of bearing offspring.

"Within the ordinary nutritive functions of the

body there is necessarily a continuous antithesis between two sets of processes—constructive and destructive 'metabolism.'

"The reader whose physiological studies have been so recent as to familiarize him with the condition of all physiological processes will find their ultimate expression in the 'metabolism,' 'anabolism,' and 'katabolism' of protoplasm.

"What takes place before fertilization is, as we have seen, very varied among animals. What takes place after fertilization is, of course, cell division. What takes place at fertilization is, however, always essentially the same.

"The head of the spermatozoön becomes the male nucleus, or pronucleus, as it is generally called, of the fertilized ovum. It enters into close association with the female nucleus, which has had its own history; it is no longer the original germinal vesicle, nor, usually, like it in appearance; it is the germinal vesicle minus the quality of nuclear substance given off in forming two polar globules.

"The female nucleus does not remain quite passive in the process, though the greater activity in bringing about the close association is certainly still exhibited by the male.

"Whitman has recently emphasized the reality of an attractive influence between the pronuclei.

"Some observers still doubt whether what can be accurately called fusion of nuclei ever occurs; and if fusion means inextricable confounding and mixing up of the male and female nuclear elements, it is almost certain that such in any case does not happen.

"There is no doubt, however, that the two nuclei become very closely associated, and, according to most observers, a double entity is formed, in which the component nuclear elements from the two originals, so diverse, are united in perfect orderly fashion.

"So exact, in fact, is this duality that when the first division of the egg takes place each of the two daughter cells has in its nucleus half of the male and half of the female elements—and so on, perhaps, in after stages.

"In the double nucleus, from the union of the male and female nuclei, Van Beneden, Carney, and others have shown that both constituents have an equal share. The one half is purely male, and the other half purely female.

"Capitulation of the origin of fertilization: (1) Plasmodial union. (2) Multiple conjugation. (3) Ordinary conjugation. (4) Union of dimorphic cells. (5) Fertilization of ovum by spermatozoön.

"True twins are of the same sex. When both are of the same sex they are both normal; otherwise one of them is normal and the other one always exhibits

the peculiar abnormality known as a 'free-martin.' The internal organs are male, but the external accessory organs are female, and there are also rudimentary female ducts. No theory has yet explained the fact of this case.

"Various naturalists have insisted on the contrast between the cells of the embryo which go to form the body and those which are set apart as reproductive organs.

"As early as 1849 Owen noted that in the developing germ it was possible to distinguish between cells which become much changed to form the body and cells which remained little changed and formed the reproductive organs.

"This view, as Brooks points out, he unfortunately afterward departed from in his *Anatomy of the Vertebrates*.

"Haechel and Rauber both drew a clear contrast between the somatic and germinal portions of the embryo, or between the body and the sex cells.

"W. K. Brooks, in 1876 and 1877, again drew attention to this significant contrast. But more explicit, in 1877, was the ingenious Dr. Jager. Referring to a previous paper, he wrote, as follows:

"'Through a great series of generations the germinal protoplasm retains its specific properties, dividing every reproduction into an ontogenetic

portion, out of which the individual was built up, and a phylogenetic portion, which is reserved to form the reproductive material of the mature offspring.

"'This reservation of the phylogenetic material I described as the "continuity of the germ protoplasm." Encapsuled in the ontogenetic material, the phylogenetic protoplasm is sheltered from external influences and retains its specific and embryonic character.'

"In 1876 Galton drew attention to the contrast between the gemmules of the ovum which go to form the body and those which, remaining undeveloped, form the sex cells.

"The developed part of the 'strip,' or gemmules of the ovum, is almost sterile, that is, without influence in heredity.

"It is from the undeveloped residue that the sexual elements are derived. In some cases it is possible to trace direct cellular continuity (1) of all between the ovum and early separation of the reproductive rudiments, and (2) between the latter and future ova and sperm.

"There is not only cellular continuity between the ovum which gives rise to parents, and the ovum which gives rise to offspring, that the cell theory demands, but there is a continuity in which the character of the original ovum is never lost by differ-

entiation. In fact, there is a continuous chain of reproductive cells quite apart from the body cells.

"This is the sense in which some authors have spoken of the continuity of the germ cells. This is certainly true in some cases. If it were true for all, the problems of reproduction and heredity would be much simpler than at present they appear to be.

"Weissmann says: 'A continuity of germ cells is now for the most part no longer demonstrable.' Yet there is nothing he more strongly insists upon than the reality of continuity between ovum and ovum.

"According to Weissmann, a portion of the specific germ plasm which the parental ovum contains is unused in the upbuilding of the offspring's body, and is reserved unchanged to form the germ cells of the next generation.

"B. S. Schultze advanced the hypothesis of two kinds of ova, but the grounds for his views are not admitted as correct; only its existence need be noticed until more observations are forthcoming.

"Darwin's theory is, as it were, an evolved woman, and Spencer's woman is an arrested man.

"Richarz founded his theory on the basis of the superiority of males, as many others have done. He says: 'Sex is not a quality transmitted from the parents, but has its basis in the degree of organiza-

tion attained by offspring. Male is a higher development in the embryo.'

"Hough thinks males are born when the maternal system is at its best; females at periods of growth, reparation, or disease.

"Tiedman and others regard female offspring as arrested in the original state.

"Valpan regards females as degenerates from primitive maleness.

"Starkweather firmly maintains that neither sex is physically the superior, but both are essentially equal in a physiological sense. He concludes that sex is determined by the superior parent, and also that the superior parent produces the opposite sex.

"Hopacker's and Saddler's statistics of 2000 births in favor of their theory, that when the male parent is the older the children are preponderatingly male, has received both confirmation and contradiction."

CHAPTER XVII.

STATISTICAL INQUIRY INTO THE PROBABILITY OF CAUSES OF THE PRODUCTION OF SEX IN HUMAN OFFSPRING, BY PROFESSOR SIMON NEWCOMB, 1904.

"1. The distinction of male and female exists in original germs, antecedent to conception, presumably supplied by the father.

"2. Sex is entirely determined by the conditions to which the germ is subject during early stages of its development. Changes produced by age in the human system are such that we may plausibly look to them as causes affecting the sex of offspring.

"When we see families consisting mainly or wholly of male or female children, it is very natural to suspect that the sex in each case may be due to some characteristic faculty of the parents, or some peculiarity of their constitution, which may or may not admit of discovery and investigation.

"The mere fact of this inequality, taken in itself, does not, however, prove anything, because it may be the natural result of those accidents which determine sex, but of which we know nothing.

"Granting the existence of constitutional or other

tendencies of the kind supposed, we may apply the term 'unisexual' to the

"What we know, to start with, is, that if some parents have a tendency greater than the normal to produce male children, then there must be a corresponding tendency, among other parents, to produce female children.

"The following data has been derived from Mr. Hunt, chief of the division of popular statistics, in the Census Office

"Families of which the children are all of the same sex, whether male or female: Of 670 families, 322 had all the same sex; 348 had opposite sexes.

"Thus we see at a glance to what extent, if any, a bisexual tendency can be found in the families enumerated.

"We may make the hypothesis that there is something in the constitution or habits of parents which results in some having a unisexual tendency in the production of male children, and others toward the production of females, which tendencies, nevertheless, elude investigation otherwise than by statistical investigation of their effects."

After thorough investigation of statistics, both in Europe and America, among the various races—Semitic, Japanese. negro, etc.—Professor Newcomb concludes:

"There are no unisexual tendencies on the part of parents sufficiently great to be of practical importance.

"A formal discussion, by algebraic methods, of the unisexual tendency.

"Sex of twins.

"The numbers derived from the statistics of twins may be applied to the case of triplets, and a comparison of the actual statistics of triplets with those derived from the statistics of twins will be of interest.

"The processes which we presuppose are these: During an unknown period of time, commencing with the moment of conception, the two germs are exposed to a series of common influences, either in the male or female direction, tending to make them of the same sex.

"As, without appreciable error, we can make abstraction of the small normal preponderance toward the male sex, we may say that in the general average this unisexual tendency will be as often in one direction as in the other.

"But these preponderating influences do not completely determine the sex. There are accidental causes operating differently, on the two growing organisms, which may result in their becoming of opposite sexes.

"The main point is that there is some preponder-

ating tendency of the pair of organisms toward one sex in some cases, and in the opposite sex in the remaining cases.

"Summary of conclusions and statistics of sex:

"1. The preponderance of male or female births probably varies with the race. Although remarkably uniform in all branches of the Semitic race, it seems to be non-existent, or quite small, in the negro race.

"2. There are no important differences as regards capacity for producing children of one sex rather than the other which are permanent in the individual.

"All fathers and all mothers are equally likely to have children of either sex except for the slight variations that may be due to age. In view of the great variety of conditions on which the conclusion is based, it seems in the highest degree unlikely that there is any way by which a parent can affect the sex of his or her offspring.

"3. The most natural inference from all the statistical data is that the functions of the father in generation are entirely asexual, the sex being wholly determined by the mother. If so, it cannot be said that one father is more likely than another to have children of either sex. This conclusion requires to be tested by making a classification of the sex of third born and the following children according to the age of the father.

"4. The sex is not determined by any one moment, by any one act, but is the product of a series of accidental causes, some acting in one direction and some in another, until a preponderance in one direction finally determines it. The statistics of twins and triplets seem to show very strongly that these accidents occur after conception, but throw no light upon the question of the time which they occupy.

"5. The first born child of any mother is likely to be a male in the proportion of about eight to seven. There is probably a smaller preponderance in the case of the second child. But there is no conclusive evidence that after a mother has had two children there is any change in her tendencies.

"6. The observed preponderance of male births in the Semitic race is due mainly to the unisexual tendency of the mother in the case of a first child."

MATHEMATICAL THEORY OF THE EFFECT OF UNISEXUAL TENDENCY.

"1. An indefinite number of pairs of parents, each pair of which may have an indefinite number of children of either sex. The treatment of this subject will include the general case of an indefinite number of causes, each of which may, on each trial, be productive of one or the other of two different effects.

"2. Taking the general average of the whole mass of couples, there is a certain normal probability (p) that a child, taken at random, will be male, and the probability (1–p) that it will be female.

"3. It may be that the probability is the same for every individual couple for the whole mass. But it may also be that for some of the couples the probability is greater than (p). In this case it will necessarily follow that for certain other couples the probability is less than (p), the latter quantity being the average for the whole mass.

"4. In order not to complicate the problem too greatly, we shall suppose that each of the individual couples belongs to one of three classes:

"A class for which the probability for having a male child has the normal value of (p). Another by which it is greater than (p) by an unknown quantity (a). And a third for which it is less than (p) by the same quantity.

"We designate the classes by A, B, C. A, representing couples with probability (p plus a). B, representing couples with probability (p). C, representing couples with probability (p minus a). The numbers of classes of A and C are necessarily equal.

"Let us put (h) the fraction of the total belonging to the two equal classes A and C; (h′) the fraction

of the whole class belonging to class B. We shall have (h plus h′ equals 1). Proceeding according to the methods of probabilities, we suppose a parent couple taken at random from the mass. The respective probabilities that this couple will belong to the classes A, B, and C are ½h, h′, and ½h. The probabilities of a male child in these general classes are: For class A, (p plus a); for class B (p); for class C (p minus a). Then, by the principle of the theories of probabilities, if a couple be taken at random from the whole mass the respective combined probabilities that the couple will be one of the classes and the child a male will be: In class A, ½h (p plus a); in class B, h′ (p); in class C, ½h (p minus a), of which the sum is (p), as it should be.

"The problem before us is to find a criterion for deciding whether the quantity (a), which we consider as the unisexual factor, and which we call co-efficient of unisexuality, is or is not of appreciable magnitude. Such a criterion is afforded by a count of males and females in families of two or more children. The theory requires that in a family of a given number of children we express the probable respective numbers of males and females in terms of the factor (a). The problem now assumes the following form: A parent couple, taken at random from the whole mass has, (n) children. What is the probability that (a) of

these children will be males and (n minus s) females? Using the notation (m/s) equals

$$\frac{n\ (n \text{ minus } 1)\ (n \text{ minus } 2)\ \ldots\ (n \text{ minus } s \text{ plus } 1)}{1 \cdot 2 \cdot 3 \cdot \ \ldots\ s} \qquad \frac{}{1 \cdot 2 \cdot 3 \cdot \ \ldots\ s}$$

we have the well-known theorem that if the probability of an event on a single trial is (p), the probability of its occurring (s) times on (n) trials is ps $^{(n)}$ equals (n/s) p^s (1 minus p) $^{n \text{ minus } s}$. Putting for (p) the three values of the probabilities given in (1), we find that the probabilities in question are:

"For class A, (n/s) (p plus a) ^{s} (1 minus p minus n) $^{n \text{ minus } s}$.

"For class B, (n/s) p^s (1 minus p) $^{n \text{ minus } s}$.

"For class C, (n/s) (p minus a) ^{s} (1 minus p plus a) $^{n \text{ minus } s}$.

"Multiplying these expressions as in (2) by the respective factors $\frac{1}{2}h$, h', and $\frac{1}{2}h$, putting for brevity n minus s equals r and 1 minus p equals q, and taking the sum of the products, we find the probability that a family of (n) children taken at random from the whole mass will comprise (s) males and (r) females to be:

"$P\,{}^{(n)}_{r\,s} = \{\frac{1}{2}\,h\,(p + a)^s\,(q - a)^s\,(q + a)^r + h'\,p'\,q'\}\,[{}^{n}_{s}]$.

"This expression may now be developed in even powers of (a), the co-efficient of the odd powers all vanishing in the form P n/s equals (A plus $A^{s^2}_{2}$ plus $A^{s^4}_{4}$ plus .. (n/s).

The value of the first co-efficients are: A equals (h plus h′) $P^s q^r$ equals $P^s q^r$. $A_2 = h\, p^{s-2} q^{s-2} (p^2 [{}^r_2] + q^2 [{}^s_2] - r\, s\, p\, q) = \frac{1}{2} h \{n(n-1)\, p^2 - 2(n-1)\, s\, p + s(p-1)\} p^{s-2} q^{r-2}$.

"For our present purpose these terms suffice to investigate unisexual deviation. It will also lead to no appreciable error to suppose p equals q equals $\frac{1}{2}$. The value of $P^{(n)}_{r\ s}$ that is, the probability of a family of (n) children will consist of (s) males and (r) females now becomes: $P^{(n)}_{r\ s}$ equals (n/s) ($\frac{1}{2}$ plus $\frac{(r \text{ minus } s)^2 \text{ minus } n}{2n \text{ minus } 1}$ by ha^2).

"We may use this formula to express the probability in question for the case of a family of any number of children, distributed in any way among the two sexes.

"Now we make a practical application of this theory by determining the numerical value of the unisexual tendency. (a) in the respective cases of twins there cited show that of such pairs 0.646 are unisexual and 0.354 are bisexual.

"Equating these percentages to the expressions for the probability we find $\frac{1}{2}$ plus $2ha^2$ equals 0.646; $\frac{1}{2}$ minus $2ha^2$ equals 0.354. Subtracting these from each other, we find $4ha^2$ equals 0.292; and hence, supposing h equals 1, a^2 equals 0.073, a equals 0.027.

"We may now consider the case of triplets in two ways: Proceeding as in the case of twins, by equating each probability to the fraction indicating the proportional number of families to which it relates, we have the equation: $\frac{1}{4}$ plus $3ha^2$ equals 0.499; $\frac{3}{4}$ minus $3ha^2$ equals 0.501. Solving these, after putting h equals 1; a^2 equals 0.0831; a equals 0.29.

"We may also proceed in another way, by substituting the expressions for the respective probabilities of unisexual and bisexual triplets the value of ha^2 derived from the case of the twins. It may be added that this relation is not changed by changing the value of (h). It is, therefore, indifferent what value we assign to (h). The co-efficient for unisexual tendency is, therefore, for triplets, a equals 0.29.

"Now, we should suppose, *a priori*, the ratio of the unisexual preponderance to the effect of the accidental causes which finally determine the sex would be the same with twins and triplets.

"It is true that the discrepancy between 0.27 and 0.29, or between 46.9 and 49.9 per cent. is not greater than might easily have been the result of fortuitous deviation.

"We may regard it as expressing a real law. We may suppose that, besides the independent cases at action tending toward one sex or the other, there is an interaction between the two organisms by which

the sex of one influences the sex of the other in its own direction.

"Apart from this, the general conclusion from triplets confirms that from twins $\frac{1}{m}$—there are not male and female germs. It would seem in this that we have a practically conclusive negation of the theory of completely determined sex, in the original germs, and may provisionally accept that of complete asexuality on the part of such germs, subject to further statistical tests."

PROCESSES IN THE DETERMINATION OF SEX SUGGESTED BY THE STATISTICS OF MULTIPLE BIRTHS.

"The view that if the sex is not completely determined in the original formation of a germ it must be determined at some definite moment of development, that there can be no intermediate state between complete asexuality and complete sexuality, is one which, at first sight, seems almost axiomatic. And yet the preceding statistics of multiple births seems to show that such is not the case, and there may be a series of causes acting first in one direction and then in the other, each of which tends to make one sex or the other more probable, until gradually the sex is definitely determined."

CHAPTER XVIII.

HEREDITY AND SEX—INTERNAL CONDITIONS.

In his recent work on *Heredity*, J. Arthur Thomson, M.A., who has been called the Ruskin of biology of modern times, discusses under the above heading, from his book, which was published in 1908, on page 494, theories of sex determination. The most feasible one of all those mentioned, according to his opinion, is that of Professor T. H. Morgan, who decides that the "determination of sex is undetermined." Dr. Thomson says:

TWO KINDS OF EGGS.

"It has often been suggested that there may be two kinds of eggs—one kind predisposed toward developing into females, and the other predisposed toward developing into males. In the same way there may be two kinds of spermatozoa similarly predisposed toward developing into males or females.

"A fertilization of an ovum predisposed to female development by a sperm predisposed to female development would naturally result in a female, and *vice*

versa. The results of the combination of an ovum predisposed to female development with a spermatozoön predisposed to male development would depend on the relative prepotency of the two gametes. In the case of hermaphrodite animals, one kind of egg and one kind of sperm would suffice.

"This solution savors a little of Columbus and the egg, but it is not to be hastily brushed aside. It is easy to see that it simply shunts the difficulty a little farther back, for what are the conditions producing the two kinds of eggs?

"But if the primary difference between male and female, between a sperm producer and an egg producer, is merely a slight physiological difference in the gearing of the metabolism; if the contrast between male and female is like the contrast between sperm and ovum, considered as cells; if the antithesis is simply a particular expression of omnipresent fluctuation in the ratio of anabolism to katabolism, then we do not see that the assumption of two kinds of ova and two kinds of spermatozoa is a mere begging of the question.

"Where there is complex dimorphism between the sexes, it is necessary to make the further assumption that all gametes, whether maternal or paternal, and whether disposed toward female production or toward male production, have a complete set of hereditary

characters of the two sexes (so far as these require the postulate of germinal representation), and that the physiological difference of protoplasmic 'gearing' determines which set is to find expression and which set is to remain latent. The drawback to the theory is that it remains an hypothesis, except in so far as there are known cases of demonstrable differences between two kinds of ova or between two kinds of spermatozoa."

"W. E. Castle has proposed an ingenious hypothesis, which also assumes two kinds of eggs and two kinds of spermatozoa, but is distinctive in the further hypothesis that 'male' spermatozoa can only fertilize 'female' eggs, and that 'female' spermatozoa can only fertilize 'male' eggs. Thus the fertilized egg represents a union of 'male' and 'female' gametes and the determination of sex is left undetermined."

TWO KINDS OF SPERMATOZOA.

"In about thirty different kinds of animals, such as the fresh water snail, Paludina, there are two distinct forms of spermatozoa, and it has been suggested that the two kinds are, respectively, predisposed toward the two sexes. But there is no definite evidence of this."

INCLUSIVE CONCLUSIONS.

"At present it does not seem safe to go farther than Morgan does when he says: 'In all species with separate sexes the potentiality of producing both sexes is present in all eggs and in all sperms; but the development of the one or the other sex is determined by some unknown internal relation.

"'The condition that leads to the development of the alternative characters may exist in the egg alone (as for the male bee), or in the sperm alone (as for certain Hemoptera), or by the combination of egg and sperm (as for the female bee).

"'Admitting that all eggs and all sperms carry the material basis that can produce both the male and female, the two conditions being mutually exclusive when development occurs, the immediate problem of sex determination resolves itself into a study of the conditions that in each species regulates the development of one or the other sex. It seems not improbable that this regulation is different in different species and that, therefore, it is futile to search for any principle of sex determination that is universal for all species with separate sexes; for, while the fundamental internal change that stands for the male or female condition may be the same in all unisexual forms, the factor that determines which of the alter-

native states is realized may be very different in different species.' "

As for Professor T. H. Morgan's theory and Dr. Thomson's discussion of it, and their conclusion that "it is futile to search for any principle of sex determination that is universal for all species with separate sexes," at that time, 1907, I was compiling for the first time my observations and experiences in the evident law of sex determination among human beings and cattle, as I had discovered it, during a period of testings that covered thirty years, and was ascertaining by induction some of the scientific facts that these eminent men have supposed from their general knowledge in biological science. The law of sex determination, as I had discovered it, required, so is seemed to me, the male and female sperm cells and male and female egg cells, that are each the complement of the other in the process of fertilization, but that did not lead me to the conclusion that therefore "the determination of sex is undetermined," for I had first discovered the law of sex determination, and afterward wrote down my observations upon the subject and some theories this law seemed to necessitate, but this was done only in the light of the knowledge that sex of human offspring and of the offspring of cattle is determinable, according to my experience, as was always manifest by the product.

CHAPTER XIX.

THE OFFICE AND PURPOSE OF THE SEXES.

The foregoing excerpts from the general history of sex and from theories of sex determination by men of science since a very remote antiquity, must convince the reader that the great division of humanity, indeed, of all living creatures, into two classes, maternal and paternal, presents one of the most difficult scientific problems of all time. And personal experience and observation must reveal the fact that in the necessity of the two sexes among human beings, and all that that must imply of sexual emotions, is continually presented and precipitated the most difficult and vexed problems of human existence—and which directly or indirectly affect very profoundly seemingly all conditions which make up the great mosaic of individual and national life. And the good and evil that accrue to mankind thereby are the results of the workings of purely natural laws and principles which may be absolutely and arbitrarily controlled, once the individual has the knowledge of them and the will to apply them.

Mother and father hearts and heads cannot think

upon the unchanging, unwavering laws written in the flesh and spirit by the necessity of the office of the two sexes without at once being confronted by the influence thereby exerted upon the destiny of the immortal souls of their boys and girls.

It is generally admitted that "There is perhaps no more interesting question in human life than the mystery of why you were born a boy or a girl. No problem of more far-reaching consequence than the power to control the sex of future generations. It has been abundantly shown that the whole current of human history would have been changed had man possessed the key to this secret of sex."

When I saw for the first time something of the tragedy in the struggle of life among men and women, even in small towns, in the crowded cities, and lastly in the metropolises, then I began to realize the great importance to humanity of the knowledge of this sex-determining law. The sight of women and girls pouring into the black heart of the city's life every day, into the foundries, factories, and mills, crowded into the anterooms of the administerers of professional opportunity for men and women, the women usually seeming to outnumber the men, and among the seething masses of humanity in the slums of great cities, and in some European countries hitched alongside the oxen to till the fields. This

may be seen in some military countries where wars decimate the men. These are among the conditions which show the value of controlling the proportionate numbers of men and women in the world. Statistics show that more boy children die than girl children. Any one who has undertaken to bring up a boy can understand this. And afterward when they become men they are necessarily more exposed to the dangers of death than women are, as a rule. And few women are able to do both the man's and the woman's share of labor in the world.

It would seem that in the simple mechanics of the proportionate number of men and women in the world lies the solving of some of the greatest moral and economic problems of modern life. All drudgery work that women may be called upon to do could be done as well by men.

In there being men instead of women for the out-of-door battle of life, I can foresee the return of something that is being lost out of the qualities natural to manhood and womanhood, a something most precious that the brutal business encounter of men with women, which must perforce be as man to man, as fighter to fighter, is destroying. A great preponderance of women tends to destroy home, rather than to establish it.

The purpose of the two sexes for the preservation

of the human species seems scarcely to be of greater importance to the races of men than the fact of the presence of purity and impurity in body, mind, and spirit, proceeding from the necessary presence of the two sexes among them.

R. Heber Newton has said: "The union of the sexes does, indeed, form the sacrament from which, and through which, is the eternal procession of life. It remains a sacrament always, even when lust ministers at the altar instead of Love, but it is then a sacrament most foully degraded, most impiously mocked. When the harlot who posed as the goddess of Reason sat upon the high altar of Notre Dame amid the orgies of the French Revolution, making a mockery of the Mass, that holy office was none the less a sacrament in that it was being sacrilegiously caricatured. This is the awful sin of Lust, that it wantons in the holy place of Love, blaspheming in the very presence of the Lord and Giver of Life, Himself. The eternal procession of life verily flows on, even through the tainted springs of impurity, but alas! with what evil forthflowings to successive generations, where such goings-forth of life should have been wholly sweet and clean and healthful.

"The source and continuity of evil are then, through the most awful desecrations of the holy sacrament of Love and Life. It is because the union

of the sexes is generally the fountain spring of life, that to poison it is such a sin as renders it man's most sacred duty to make that union a joining together of souls as well as bodies, a marriage of love and not a cohabitation of lust, a reverent act of the child of the 'Lord and Giver of Life,' and not the coupling of flies.

"The ethical heart of the drama was even more clear in the first draft of the poem, which closed with these lines:

"'Great is the charm of desire,
Greater the power of renunciation.'"

(From Criticisms and Appreciations of "Parsifal," by R. Heber Newton).

APPENDIX.

MENSTRUATION IS NOT A SIGN OF OVULATION OF OVA.

Perhaps there is no scientist of to-day that would maintain that menstruation is the only manifestation of ovulation, because of the fact that ovulation may also occur coincident with this phenomenon as well as during the intermenstrual period, as it does with women. So far as I have been able to find records on this subject, the authorities of today are of the same opinion as Dr. Frederick F. Lee, as quoted previously (see p. 84).

There is, perhaps, no general law in woman's organism more variable than the period of menstruation. The following are a few of the different phases of its variation that have come under my observation, and which seem to show chiefly that menstruation is a manifestation simply of the necessity of menstruation.

I have known several mothers of large families who say that between the births of some two of their children, which was usually a period of eighteen months, they would not menstruate at all, and though no sign of this phenomenon occurred, they

became pregnant with the other child, and in due time gave birth to healthy, normal babies.

There have been other women who have said that within four weeks after the birth of a child, menstruation began with them and continued healthily and normally up to the time of the next pregnancy, which not infrequently would occur two years after the last birth; and these women nursed their own babies.

Then there was a case of two women who gave birth to healthy normal children—that is, each one of these two had one child—after the climacteric period had passed with them some five years. And, during the five years, neither one of them, either before or after the birth of their child, showed any signs of menstruation

And, again, I have known women in advanced stages of tuberculosis, and who said because of the disease they had ceased to have any sign of menstruation, to give birth to children.

There was a young woman whom I knew, and who was a superb specimen of animal beauty and strength, who never during her life had any sign of menstruation except, from time to time, the merest faint spot of colored substance would appear, and afterward, when she was married, though this condition did not change, she gave birth to fine healthy, normal, and handsome children.

A HYBRID SQUASH.

There was one hybridization from my experiments that might be of interest to others. This was the hybridization of two squashes, the small scalloped summer squash and the Hubbard squash. The hybrid squash resembled a green scalloped bowl of yellow custard, and was about eight inches in diameter and twenty-four inches in circumference. The main body had the greenish-gray color of the Hubbard squash, being about four or five inches deep, and this was terminated by a straight brim, edged with an appearance of green beading. Coming up out of this was the summer squash, resembling egg custard, and retaining its scalloped effect, thus completing the idea of the unevenness of the top of a custard. The meat of this fantastic hybrid was a decided improvement upon the quality of both its progenitors, being daintier, sweeter, and very delicious when baked, and, above all, a beautiful thing to behold.

THE FREE-MARTIN.

"In tne free-martin the external appearance of the calf is that of a heifer, but the uterus is only rudimentary and there are no ovaries." The late Professor James B. Wood, in 1868, raised and killed a

free-martin, and upon examination of the calf, he says the uterus was rudimentary, and there were no ovaries.

BEEF CHYLE AS NOURISHMENT FOR INVALIDS SUFFERING FROM STOMACH TROUBLE.

There are many tidbits in a freshly slaughtered animal that may be used for food, but are necessarily lost when meat must be transported some distance. We found the chyle of the lacteal intestine of beeves a dainty and delicious food. This strip of intestine is about a yard and a half long, and contains the chyle, the milk fluid which is separated from digested matter in the stomach, and is absorbed by the lacteal intestine and then assimilated into the blood.

In fact, chyle is the last process in the stomach's preparation of food for the nourishment of the creature. It seems probable to me that it might be used as nourishment for people who are supposed to be starving, because their stomachs are incapable, for any reason whatever, of properly digesting food, as this substance could be injected into the intestines of a person, and would no doubt be assimilated directly into his blood and thus nourish him without any effort on the part of his stomach. It should in all cases be the chyle from the body of a healthy

young beef, and if possible retain the animal heat of the beef when used. It should not be cooked when used for invalids.

AN ATTEMPT TO CONVEY THE KNOWLEDGE OF THE SEX-DETERMINING LAW TO THE CZARINA OF RUSSIA.

Countess H. S., of London, England, recognizing the importance of being able to determine the sex of a child, undertook to assist me to convey this knowledge to the Czarina, in 1897. Accordingly, she discussed the matter at length with various people in London whom she thought would be able to help her to do this, but from everyone with whom she talked she received only discouragement, and so she discontinued the attempt.

After the birth of the Czarina's fourth daughter, again I undertook to convey to her this knowledge. And at the advice of the Russian Consular Office in San Francisco, I sent by registered letter, directly to the Czarina, these directions for determining the sex of the child. And I may add that enclosed with these directions was a letter commending me to Her Imperial Majesty, by a prominent clergyman of San Francisco.

That communication never came back to me,

nor did I ever get word of its arrival, but I do not mean to say bv this that the Czarina received my letter.

THE RIGHT AND LEFT LOCATING OF ORGANS AND THEIR CONSEQUENT DIFFERENCE IN CHARACTERISTIC QUALITIES.

"Most people use the right eye, leg, arm, in preference to the left; but, exceptionally, some use the left instead of the right.

"In man, sight, hearing, and speech are closely connected with mental operations, at least, so far as they give rise to or express ideas.

"The two eyes are necessary to perfect vision; but the psychic visual centre, which receives ideas or meanings conveyed by objects seen, is on the left side of the cerebrum, except in left-handed people; in left-handed people it is reversed, and the psychic centre of the brain is on the right side of the cerebrum.

"The same may be said of the sense of hearing, the psychic auditory centre being on the left side, except in left-handed people, when it is on the right.

"There can be no doubt of the fact of a natural dextral preëminence, and also that left-handedness is congenital, difficult, if not impossible, to correct entirely, and not due simply to habit.

"It would appear that there must be some condi-

tions of organization which produce dextral pre-eminence, in a majority of persons, and left-handedness as an exception; but what this condition is it is difficult to determine.

"An explanation offered by some anatomists is that the right subclavian artery arises nearer the heart than the left, that the right arm is better supplied with arterial blood, developed more fully, and consequently is more commonly used in preference to the left; but the exceptional preëminence of the left hand cannot be explained in this way.

"Boyd has shown that the left side of the brain, almost invariably, exceeds the right in weight by about one-eighth of an ounce. This fact points to a predominance of the left side of the brain, which presides over the movements of the right side of the body.

"While it is not yet possible to explain why the left side of the brain has peculiar psychic functions, not possessed by the right side, it is, nevertheless, true that intellectual processes take their origin mainly, and in some instances entirely, in the left half of the cerebrum.

"Pregnancy is attended with a temporary hypertrophy (enlargement) of the heart. It is mainly the left ventricle that is thickened during uterogestation, and the increase of the weight of the heart amounts at full term to more than one-fifth. After delivery,

the weight of the heart returns nearly to the normal standard." (Flint.)

"After the third month the umbilical cord and its bloodvessels elongate more rapidly than is required by the increased size of the amniotic cavity. They consequently become twisted, the two umbilical arteries winding around the vein, in a spiral direction.

"The direction of the spiral is not always the same. Professor McLane has recorded observations in regard to this point upon 260 umbilical cords, at term, partly in private practice, and partly in the Nursery and Child's Hospital, New York. Of this number, in 138 of the cases the direction of the spiral was from left to right; in 112, from right to left; and in the 10 remaining instances it was doubtful, the twist being too imperfectly marked for decision. This gives nearly the following percentage as the result of all the observations: From left to right, 53 per cent.; from right to left, 43 per cent.; indeterminate, 4 per cent." (Dalton.)

"The umbilical cord is distinct at about the end of the first month, and as development advances the vessels consist of two arteries coming from the body of the fetus, which are twisted usually from left to right, around the single umbilical vein. In addition to the spiral turns of the arteries around the vein, the entire cord may be more or less twisted, probably from the movements of the fetus." (Flint.)